The Southern Wide-field Gamma-ray Observatory

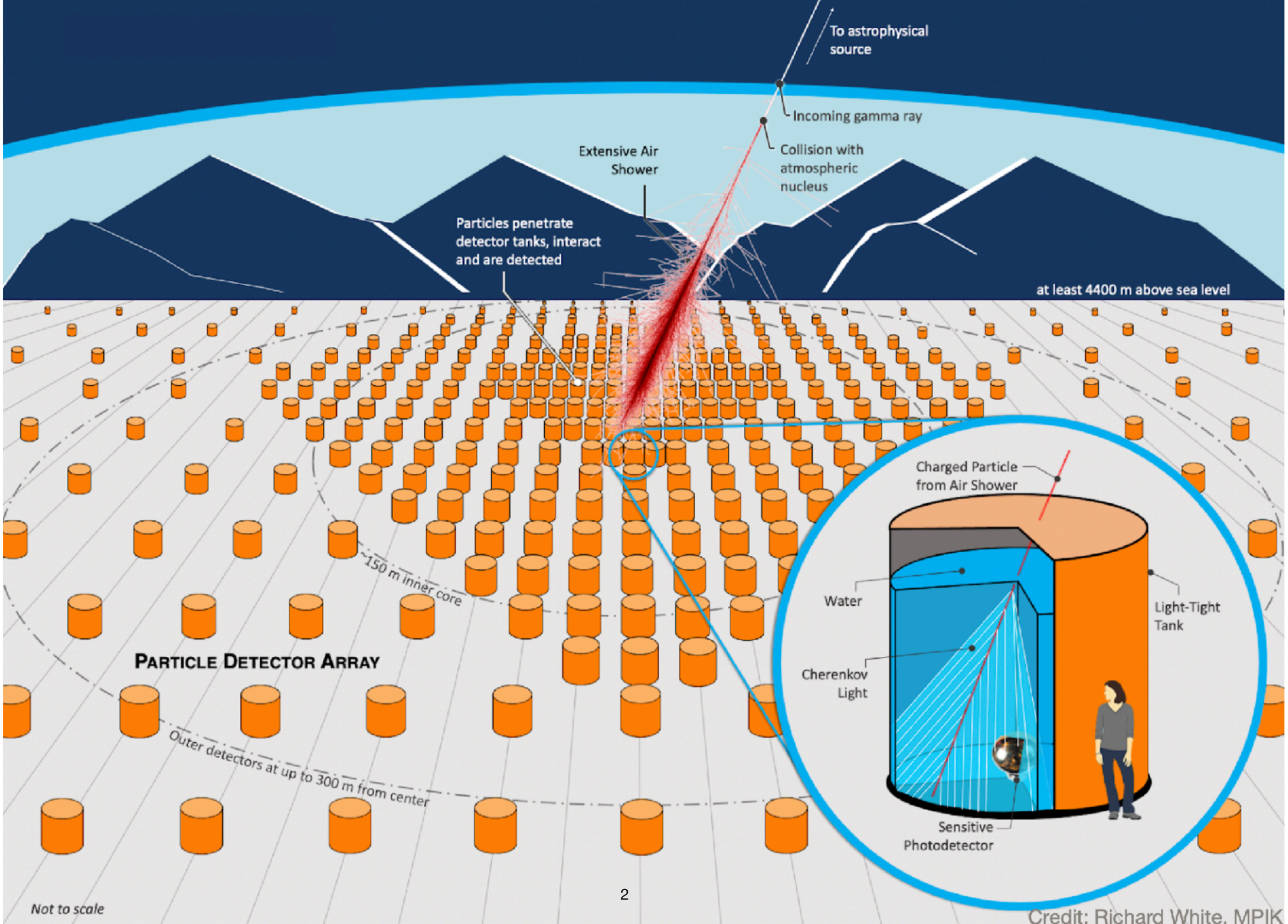
A next generation particle detector array to survey the Southern Sky

Radboud University

Max-Planck-Institut für Kernphysik Heidelberg

Harm Schoorlemmer

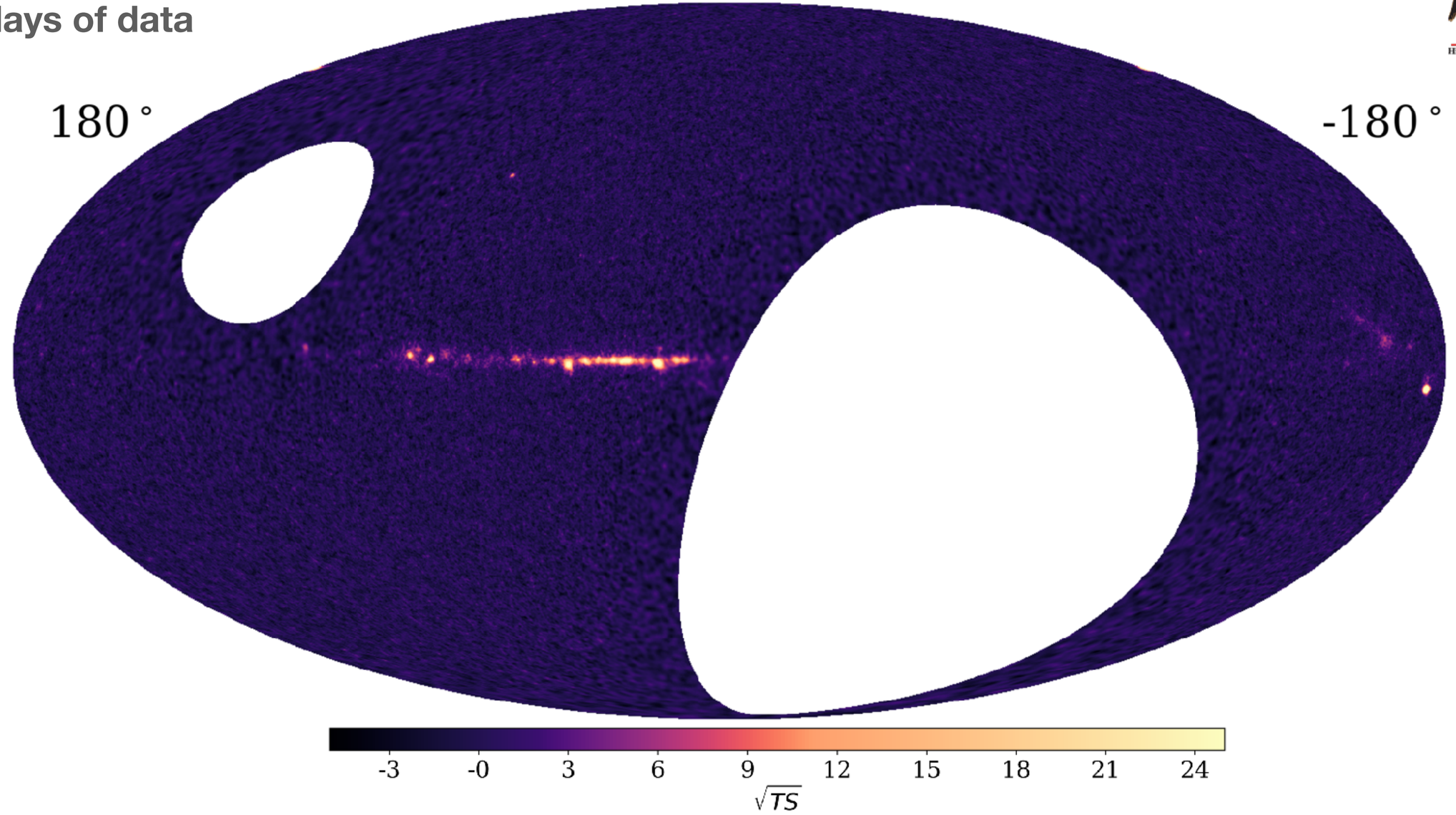
for the SWGO collaboration



Credit: Richard White, MPIK

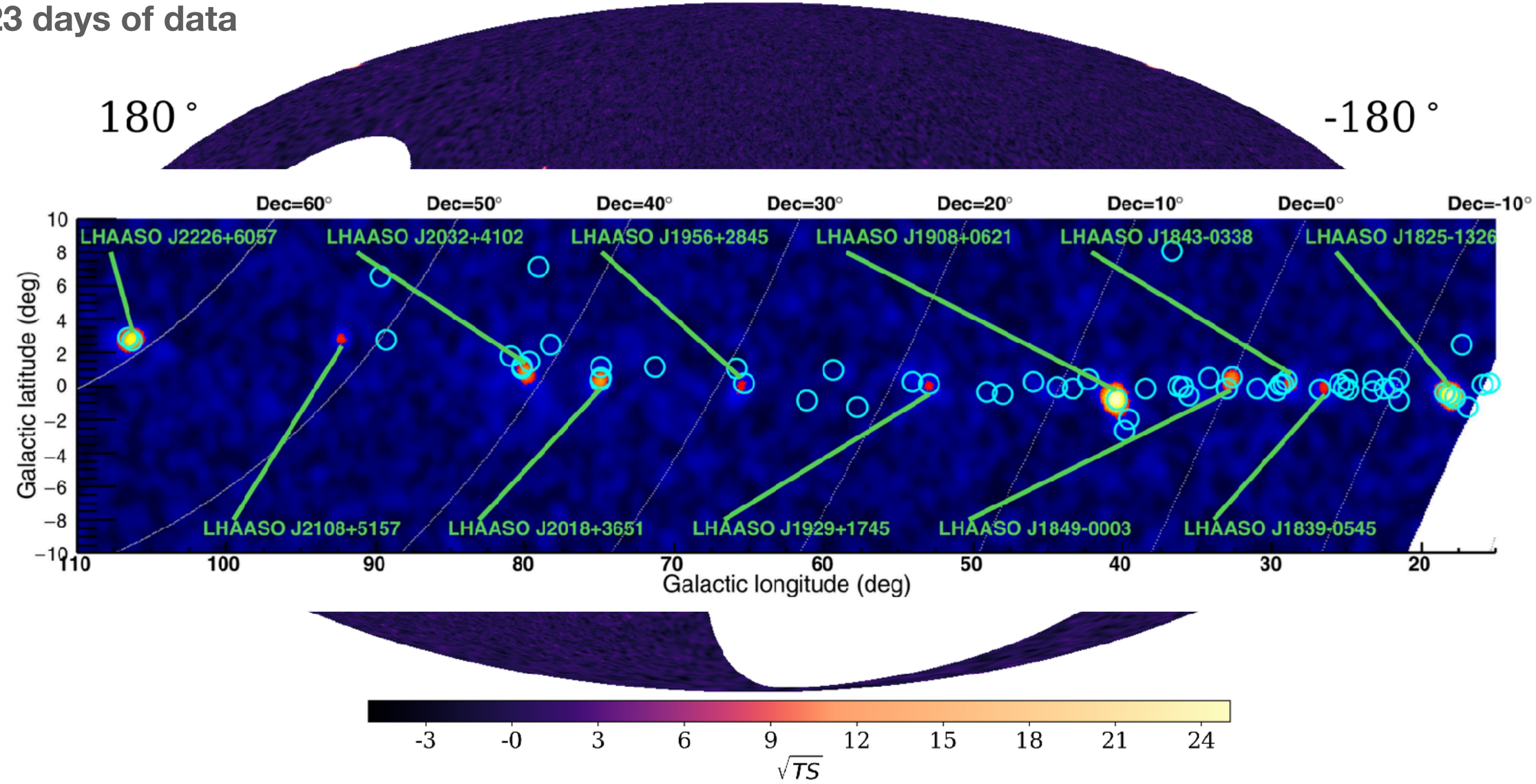
The northern gamma-ray sky as seen by HAWC

1523 days of data

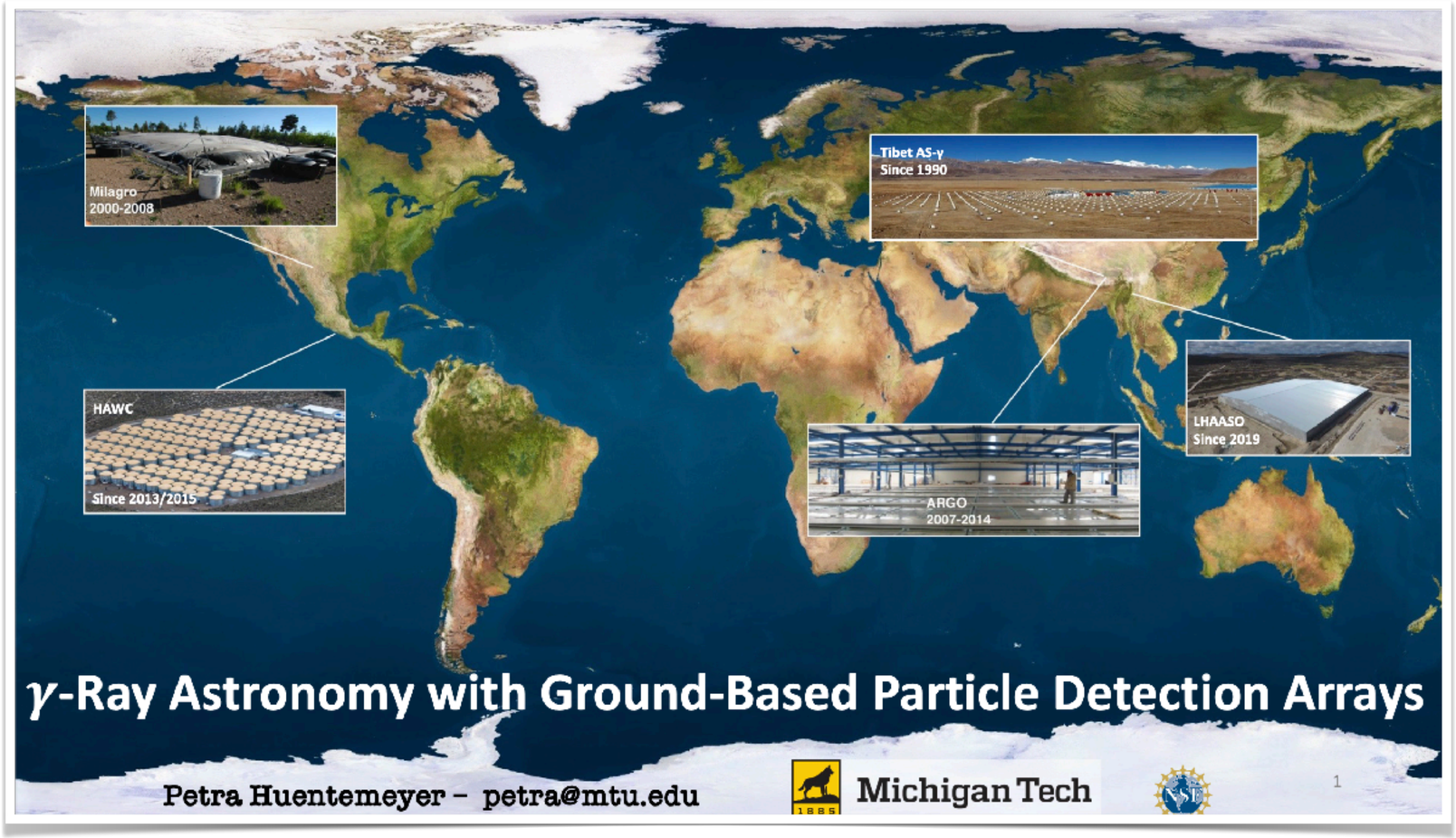


The northern gamma-ray sky as seen by LHAASO

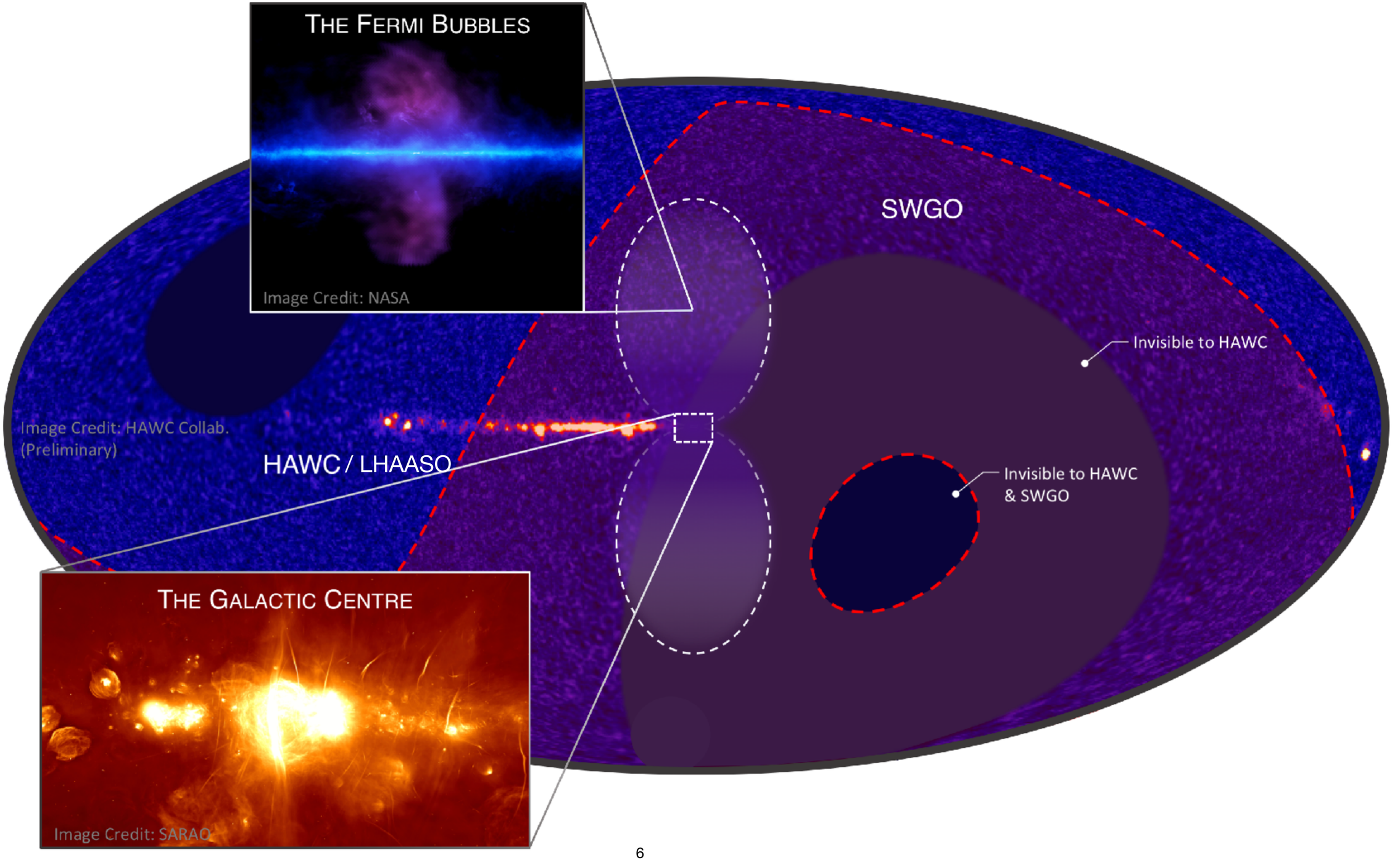
1523 days of data



From Petras Highlight talk on Monday!



No observatory in the South!

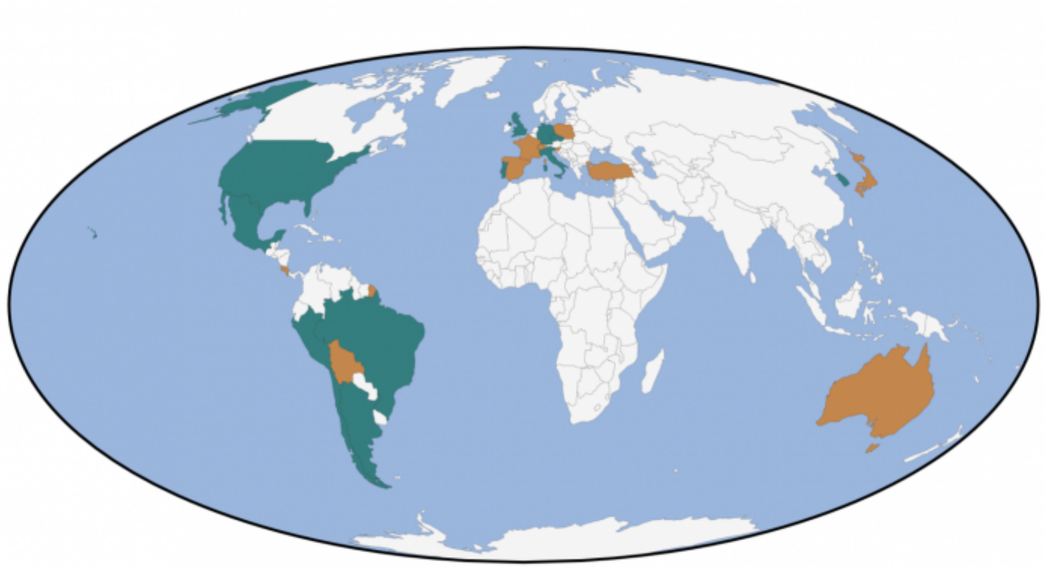

THE FERMI BUBBLES
Image Credit: NASA
SWGO
Invisible to HAWC
Image Credit: HAWC Collab.
(Preliminary)
HAWC / LHAASO
Invisible to HAWC
& SWGO
THE GALACTIC CENTRE
Image Credit: SARAO

Who & What is SWGO

International collaboration of scientists that aims to build a wide-view gamma-ray observatory in the Southern Hemisphere

The SWGO collaboration was formed to facilitate common R&D activities to design and propose such facility

47 Institutes in 12 countries + supporting scientist



Countries in SWGO

Institutes

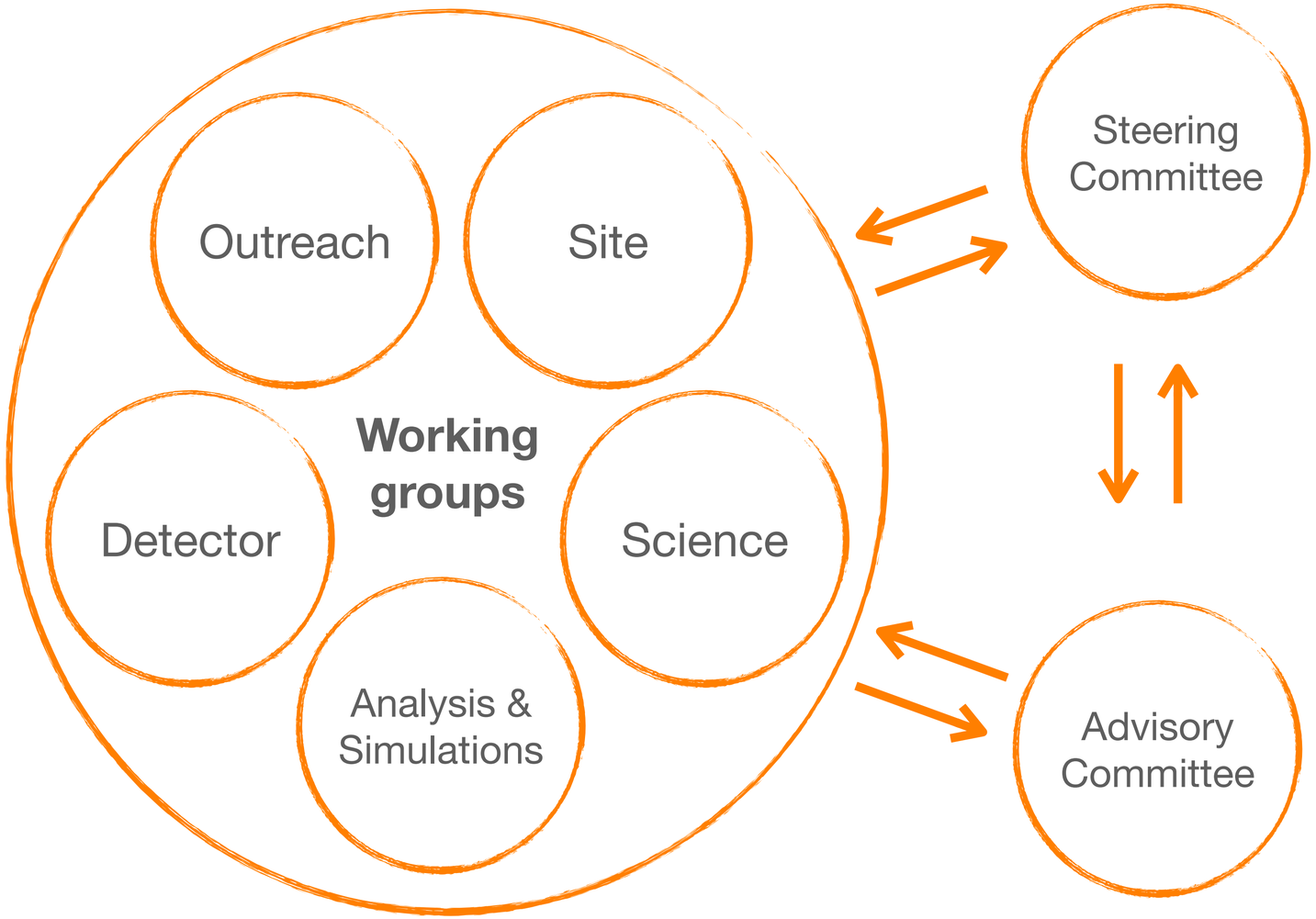
Argentina*, Brazil, Chile, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom, United States*

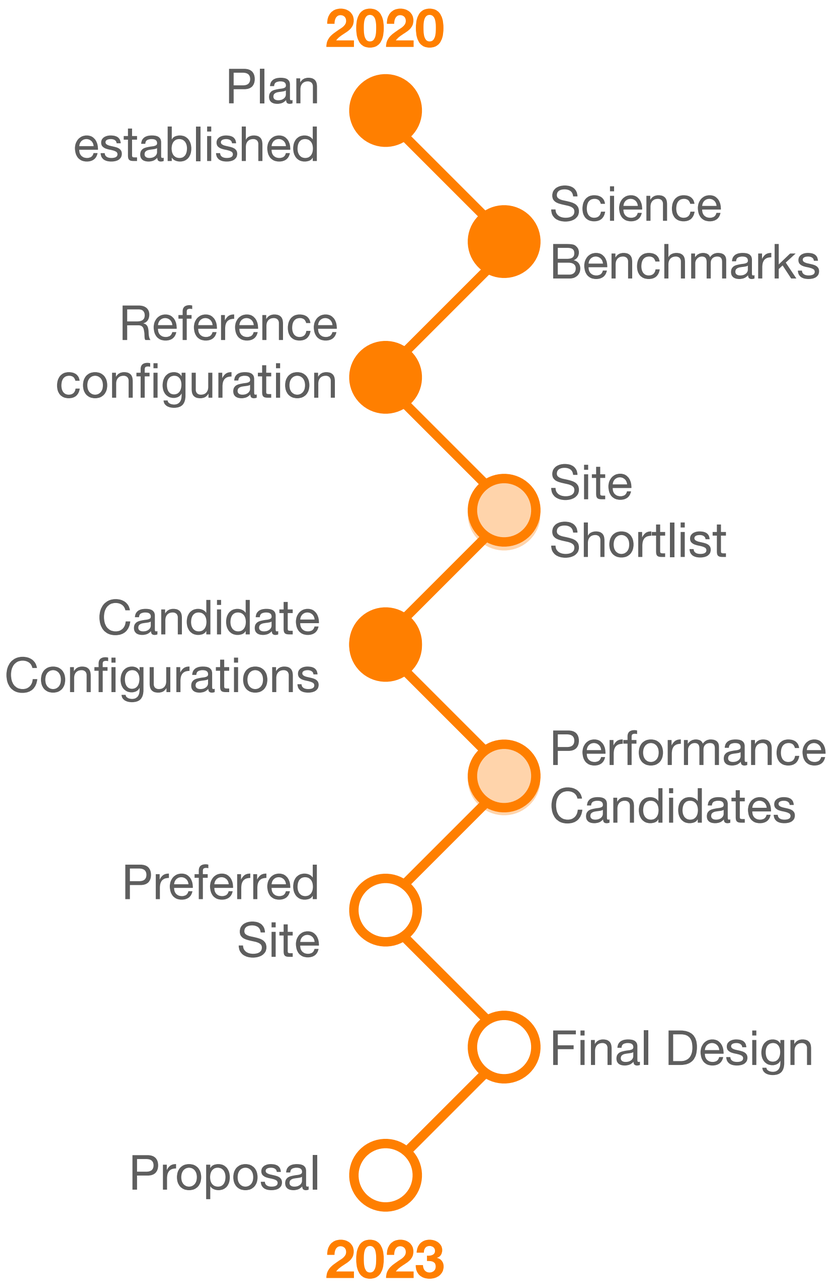
Supporting scientists

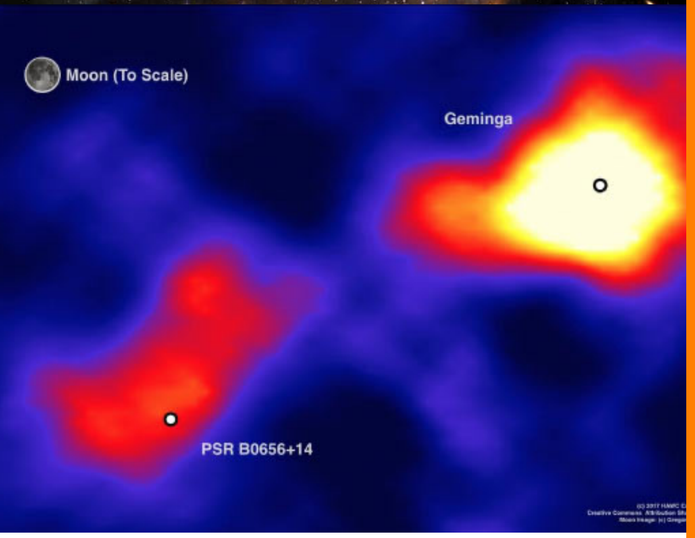
Australia, Bolivia, Costa Rica, France, Japan, Poland, Slovenia, Spain, Switzerland, Turkey

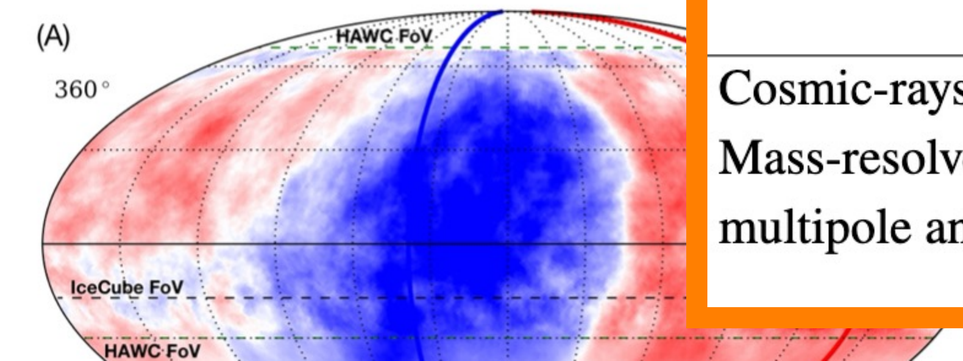
**also supporting scientists*

SWGO organisation

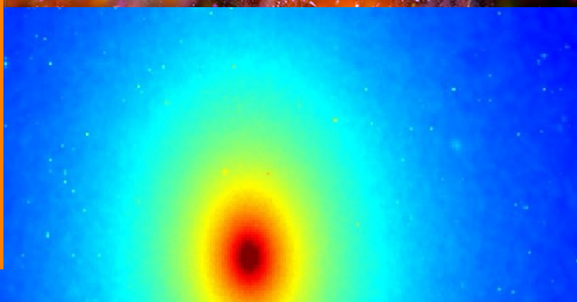




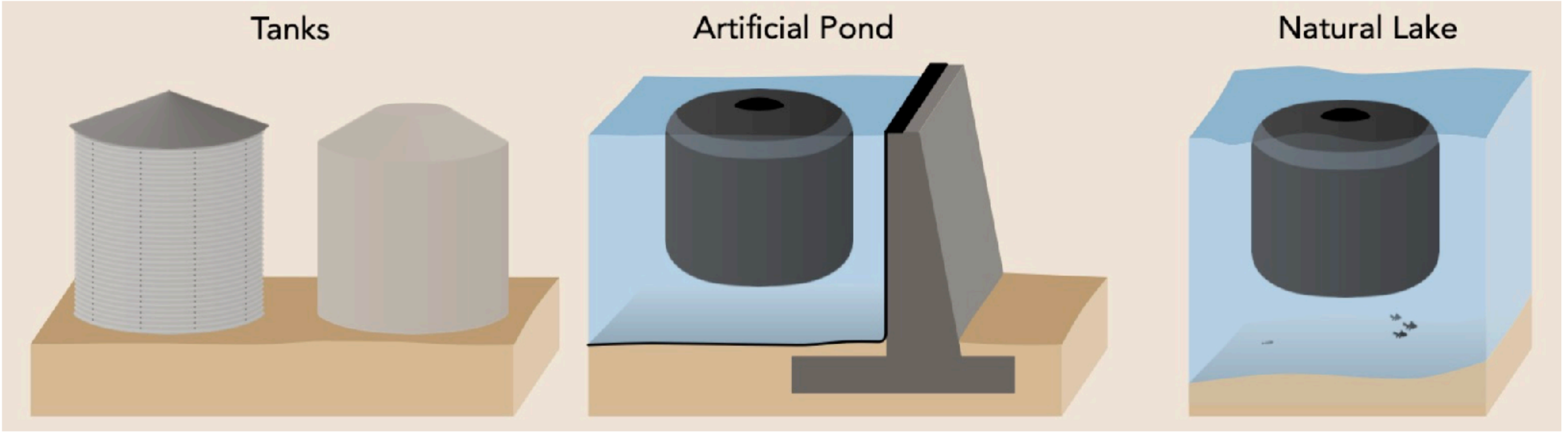




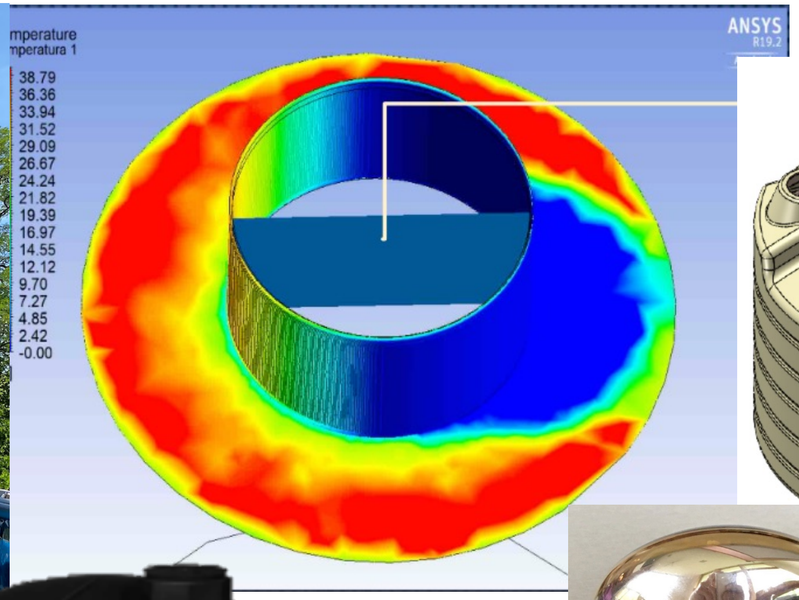
Science Case	Design Drivers
Transient Sources: Gamma-ray Bursts	Low-energy sensitivity & Site altitude[a]
Galactic Accelerators: PeVatron Sources	High-energy sensitivity & Energy resolution[b]
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity & Angular resolution[c]
Diffuse Emission: Fermi Bubbles	Background rejection
Fundamental Physics: Dark Matter from GC Halo	Mid-range energy sensitivity Site latitude[d]
Cosmic-rays: Mass-resolved dipole / multipole anisotropy	Muon counting capability[e]

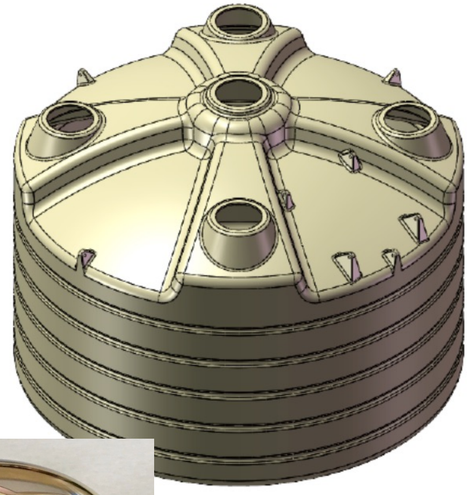


Design Options

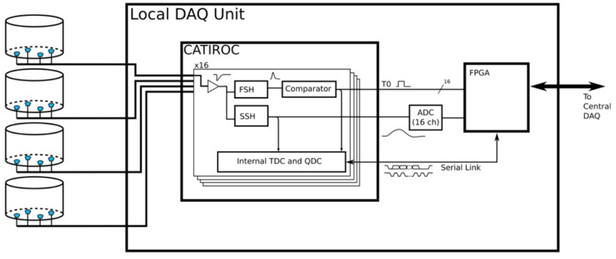


- Exploring three concepts for the detector units
  - → Tanks (like HAWC), Artificial Pond (like LHAASO) and Natural Lake
- …as well unit dimensions, photosensors, +++
  - → Performance/cost optimisation


ANSYS
R19.2
38.79
36.36
33.94
31.52
29.09
26.67
24.24
21.82
19.39
16.97
14.55
12.12
9.70
7.27
4.85
2.42
-0.00

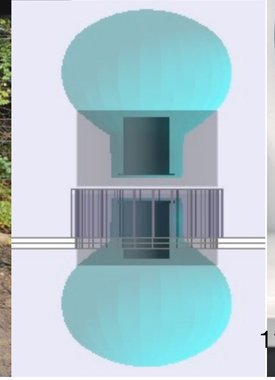



TYPE R15458-20
MADE IN JAPAN


Local DAQ Unit
CATIROC
x16
FSH
Comparator
SSH
Internal TDC and QDC
T0
16
ADC
(16 ch)
FPGA
To
Central
DAQ
Serial Link

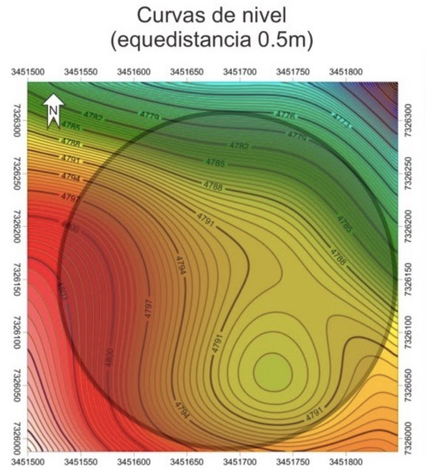

Rotoplas

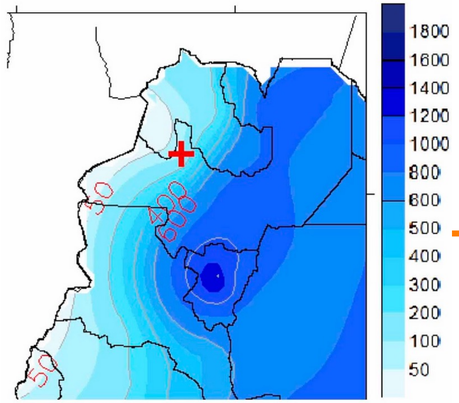

Rotoplas
Rotoplas
Rotoplas

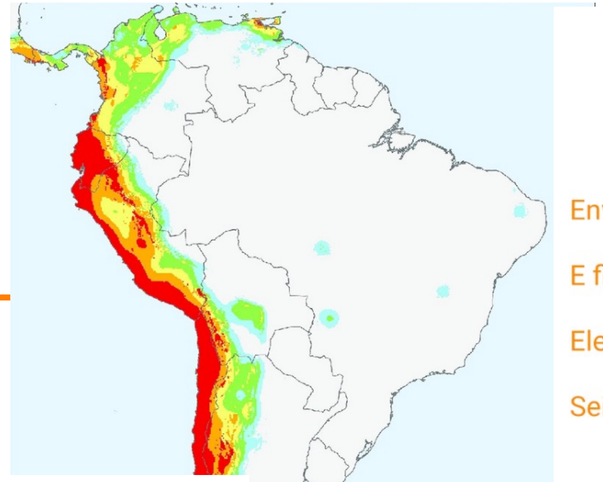


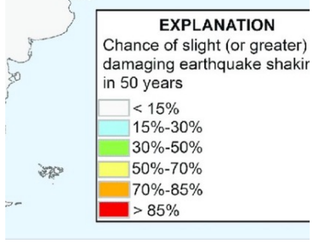

SiNEN
WI-LEN

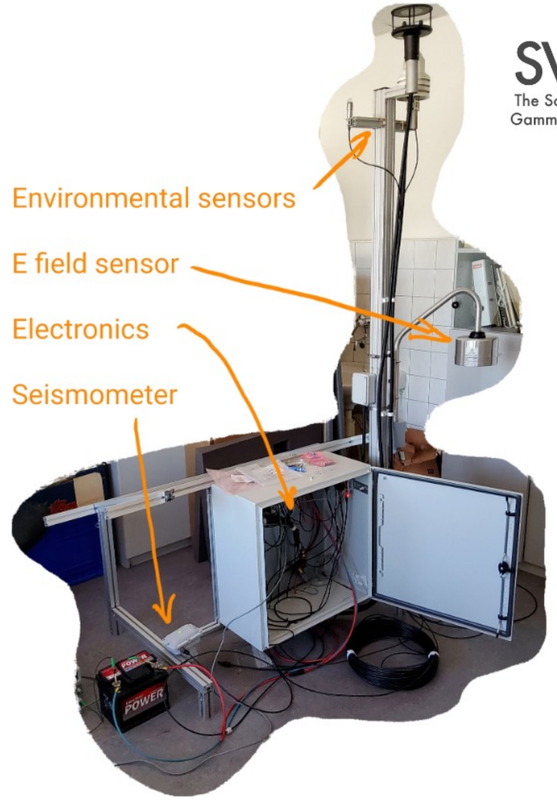

Bolivia 4.7k
Chile 4.8 k
Peru
Mina Chungar (Peru)
Lima District
Huascacocha Lagoa (Peru)
Lake Sibinacocha (Peru)
Imata (Peru)
Bolivia
Chile
ALMA site (Chile)
Alto Tocomar (Argentina)
Cerro Armazones (CTA-S...
Argentina 4.8 k
Peru 4.9 k



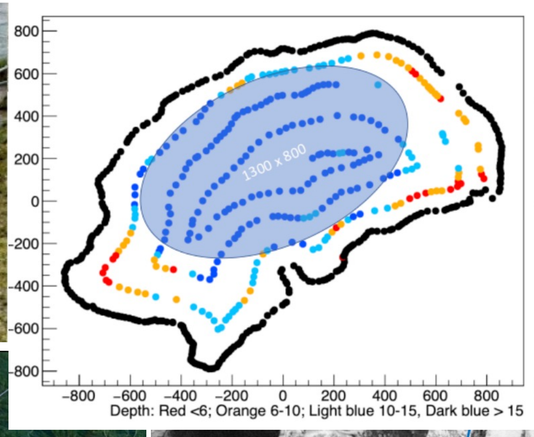


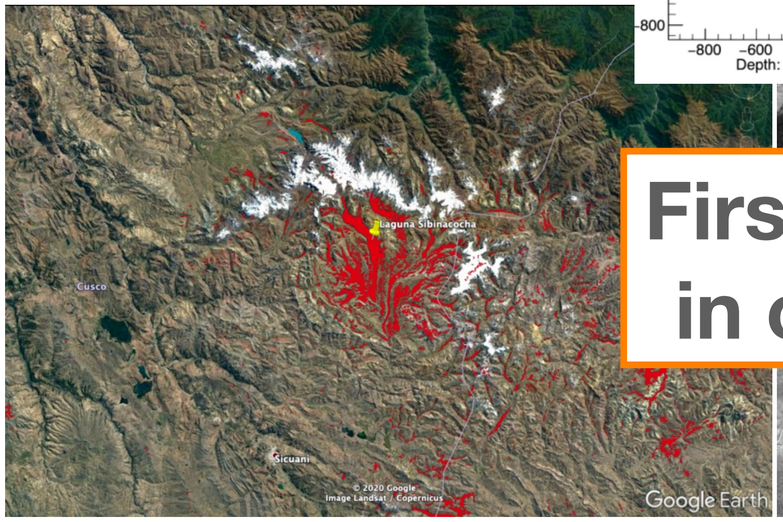


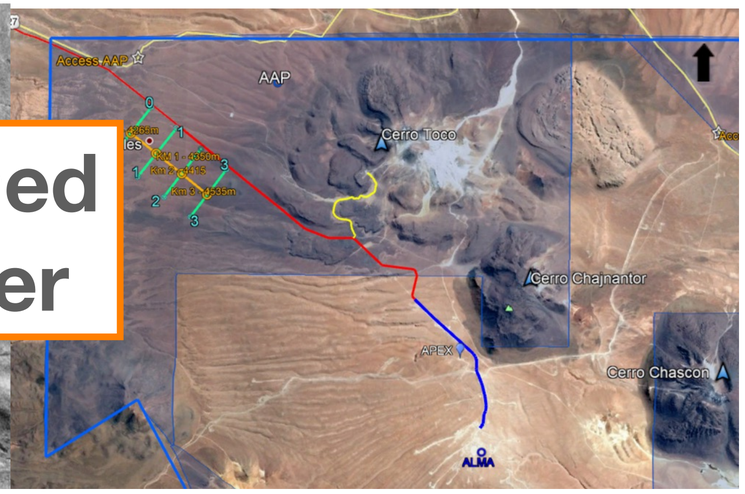




SWGO
The Southern Wide-field Gamma-ray Observatory



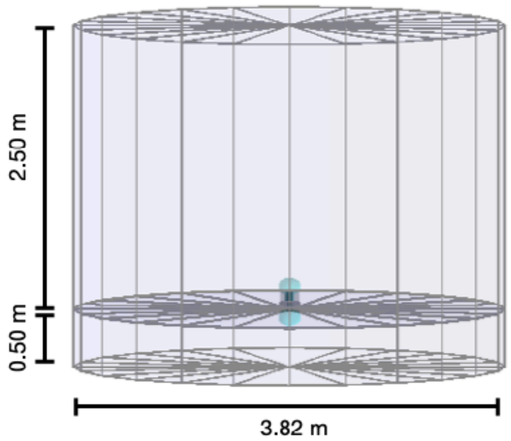




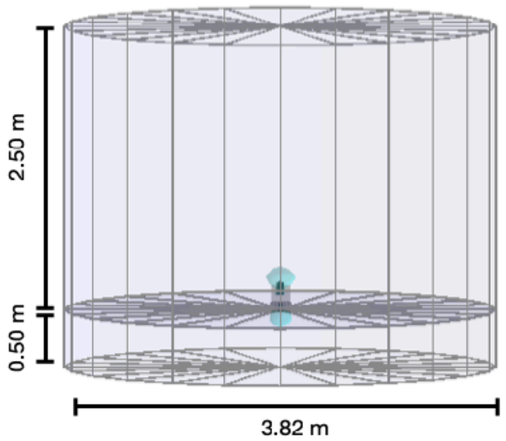
First site visits planned in coming September

Detector unit variations

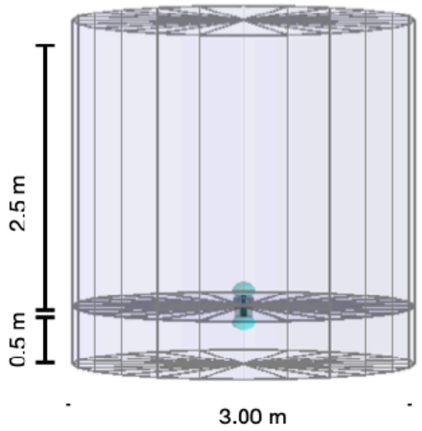
A



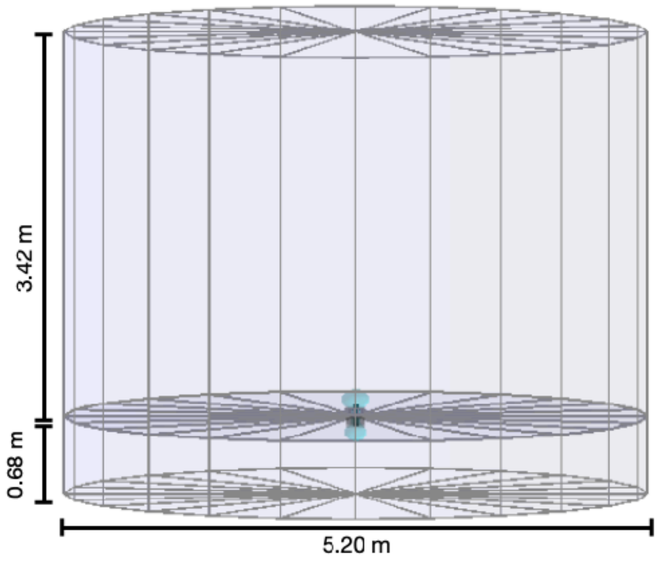
B



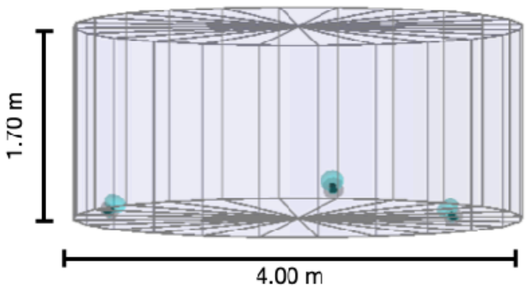
C



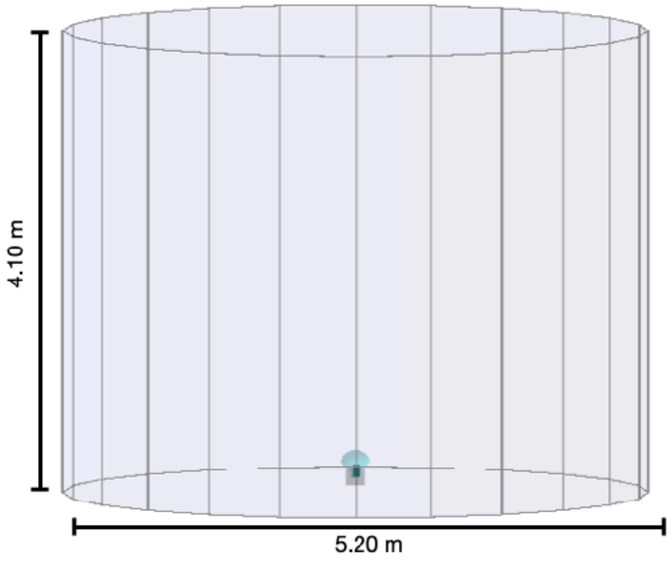
D



E

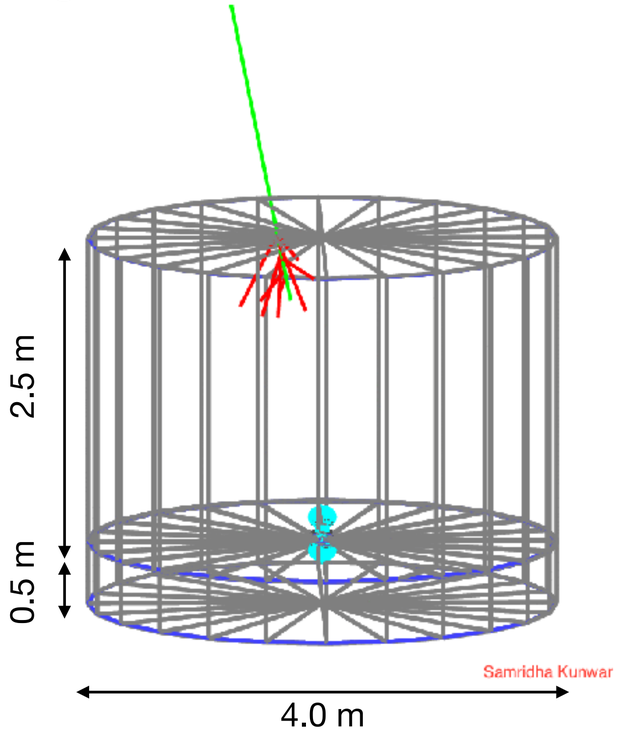


F

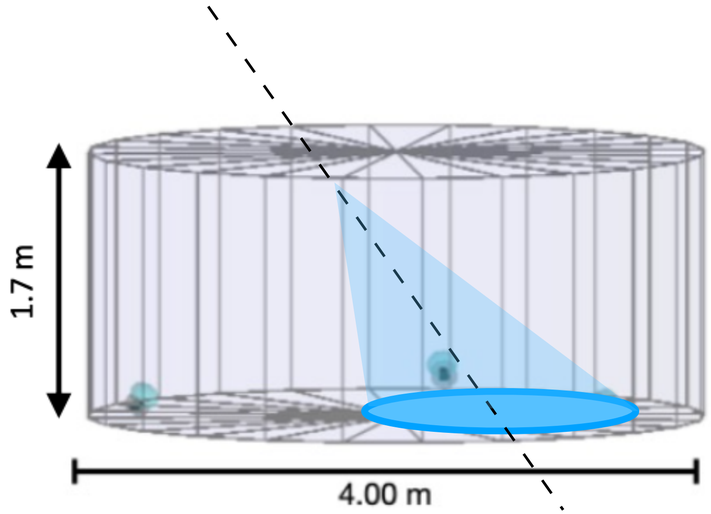


Muon identification key for background rejection

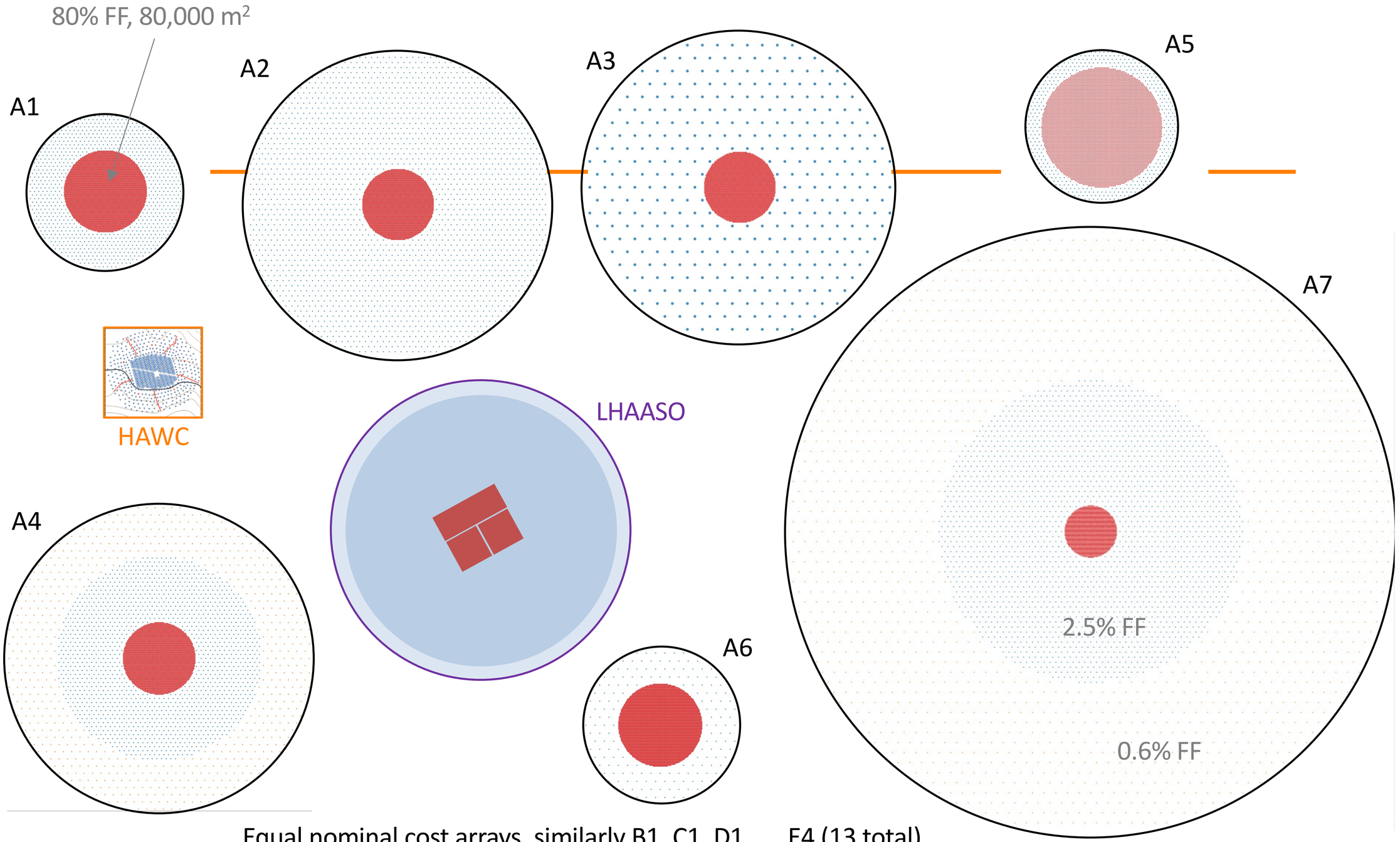
Two compartments:
Shielding from top compartment



Multi-sensor:
Exploit asymmetries in signal distributions to identify muons*



* using machine learning techniques to optimise performance



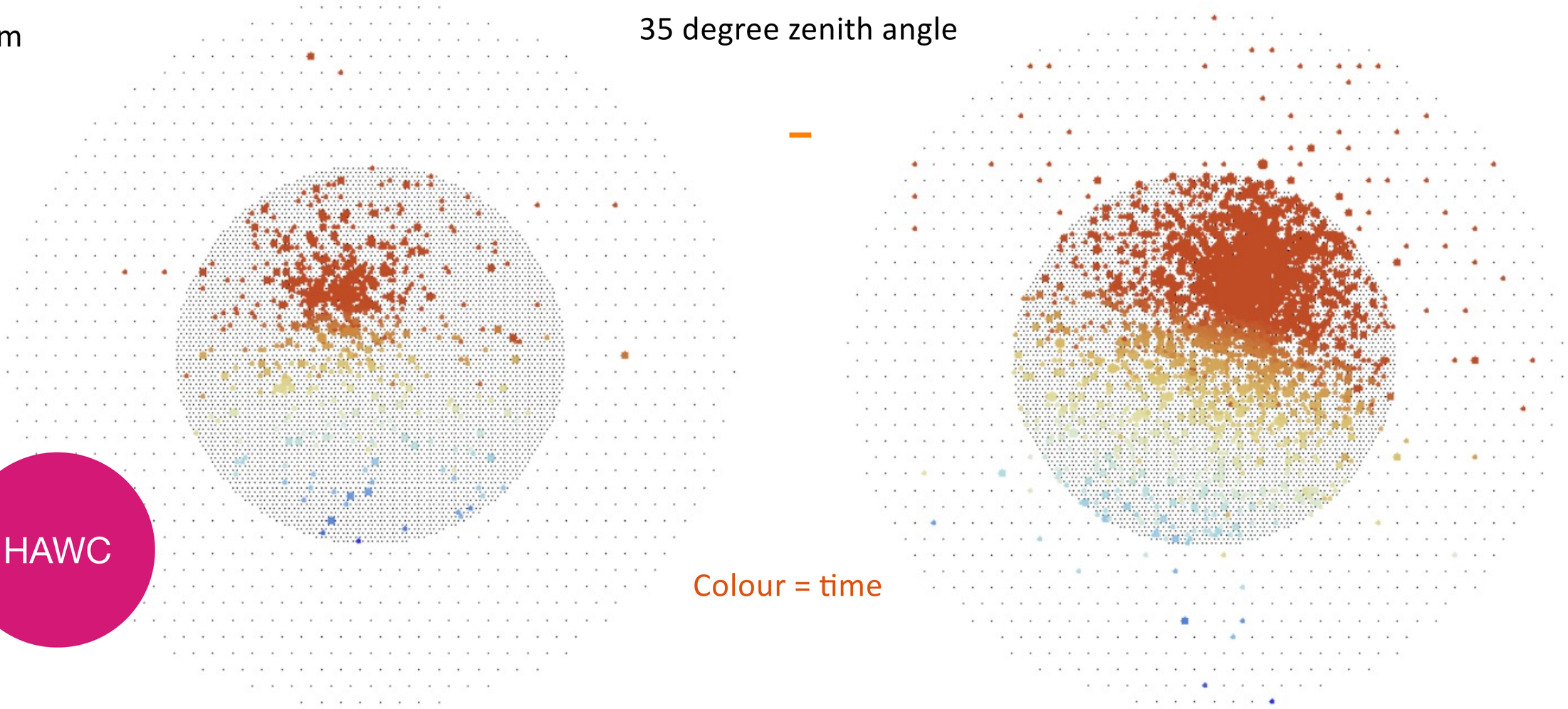
Equal nominal cost arrays, similarly B1, C1, D1, …, E4 (13 total)

600 GeV

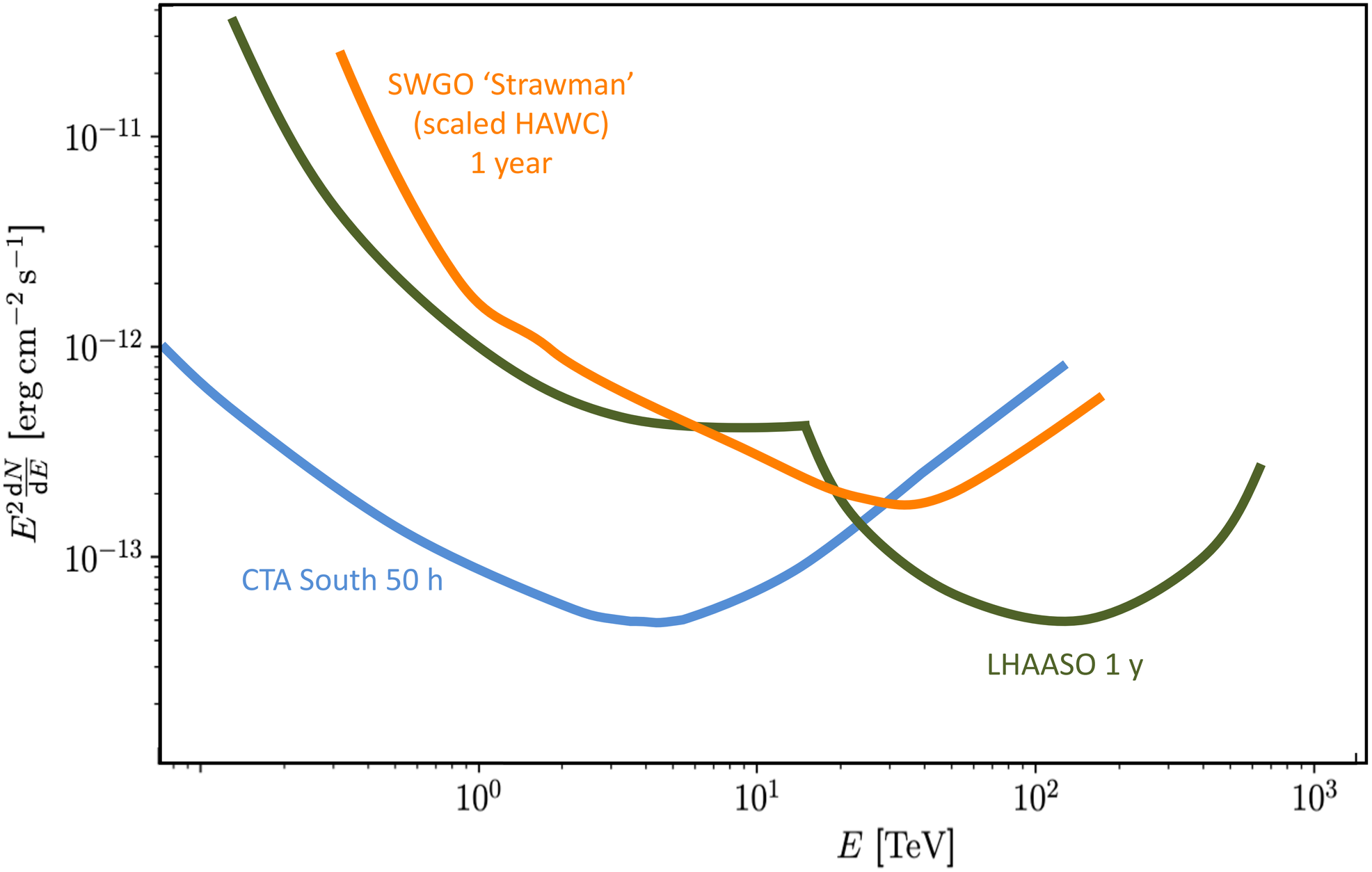
14 TeV

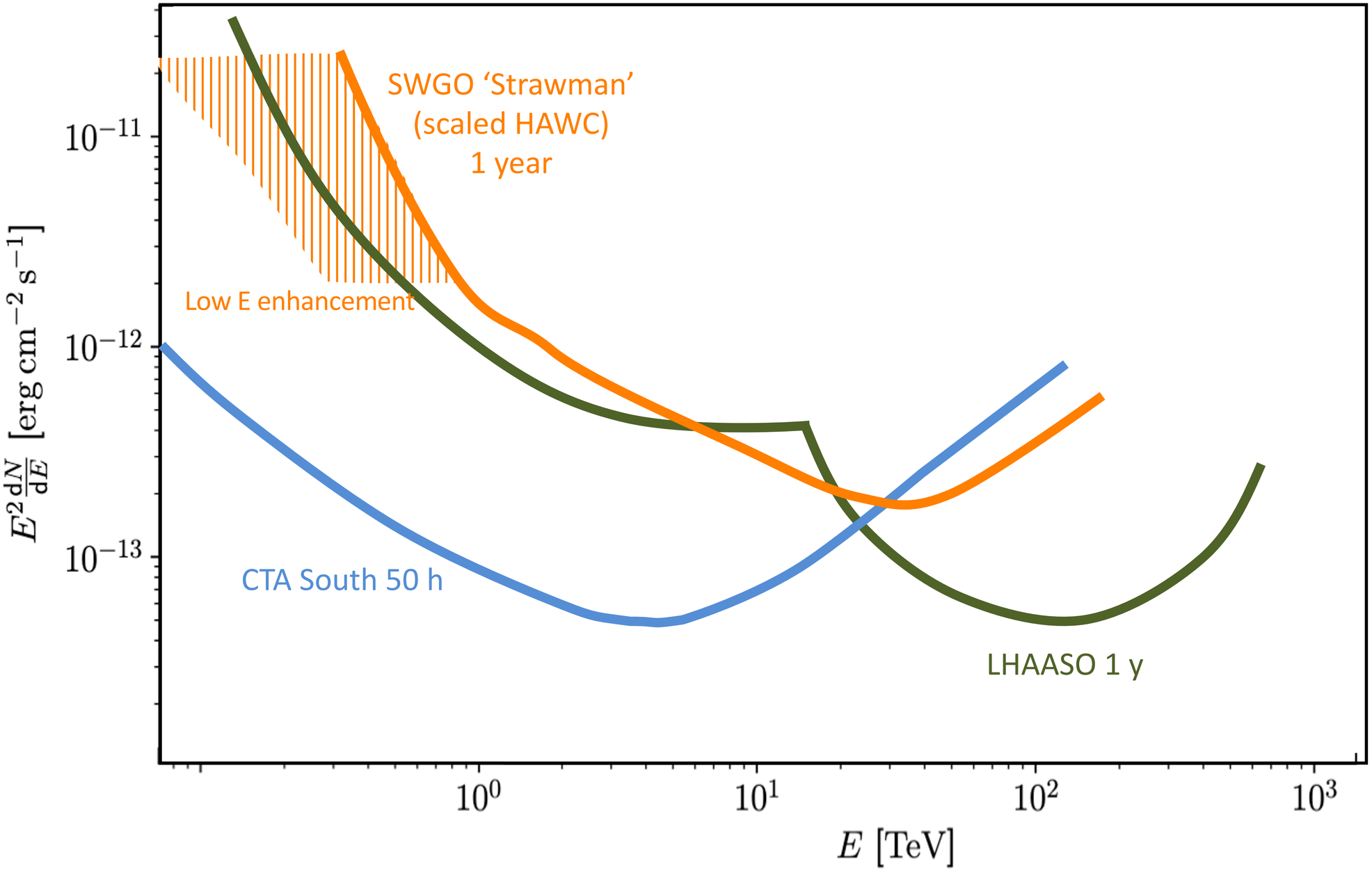
500 m

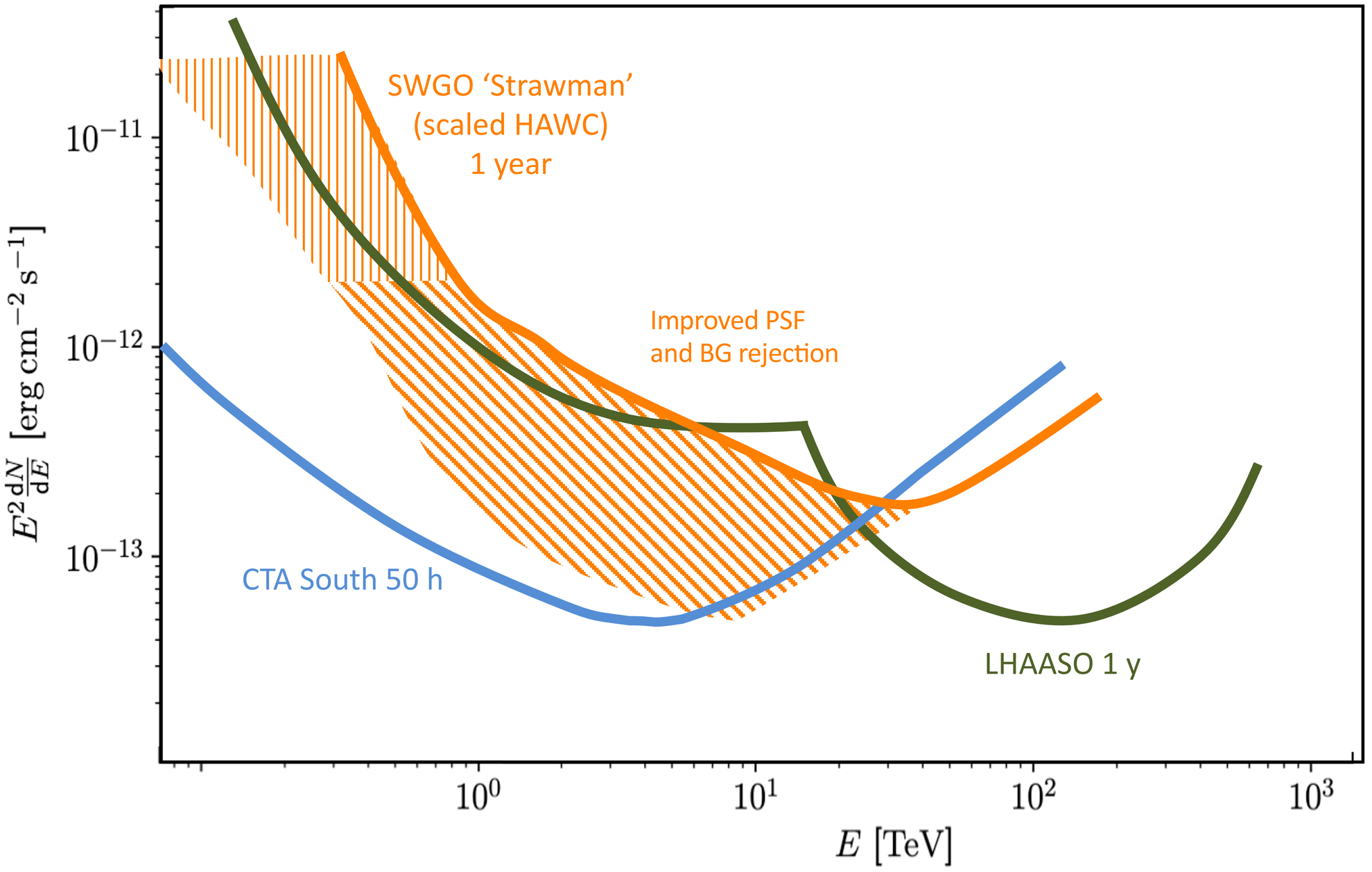
35 degree zenith angle

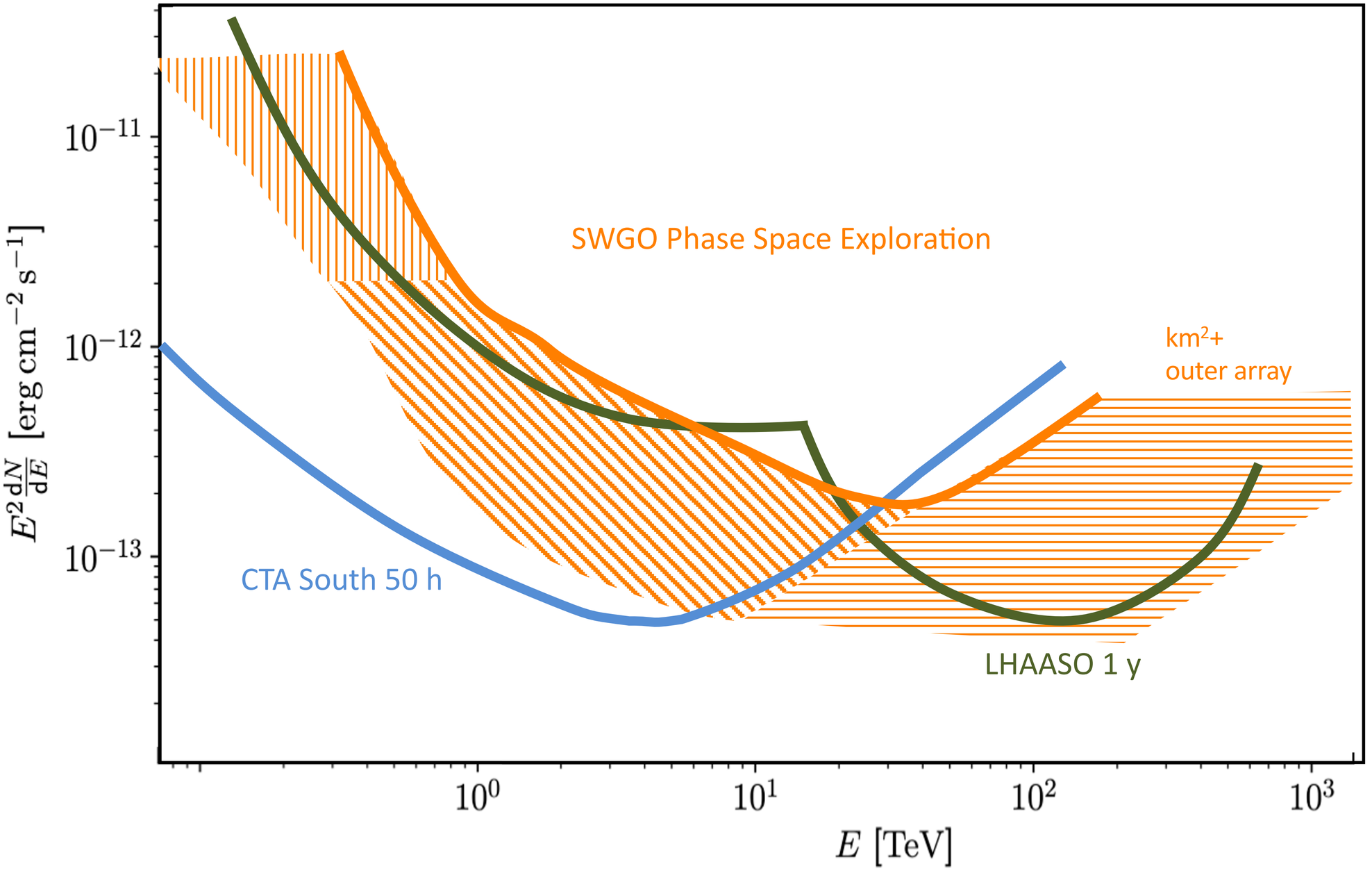


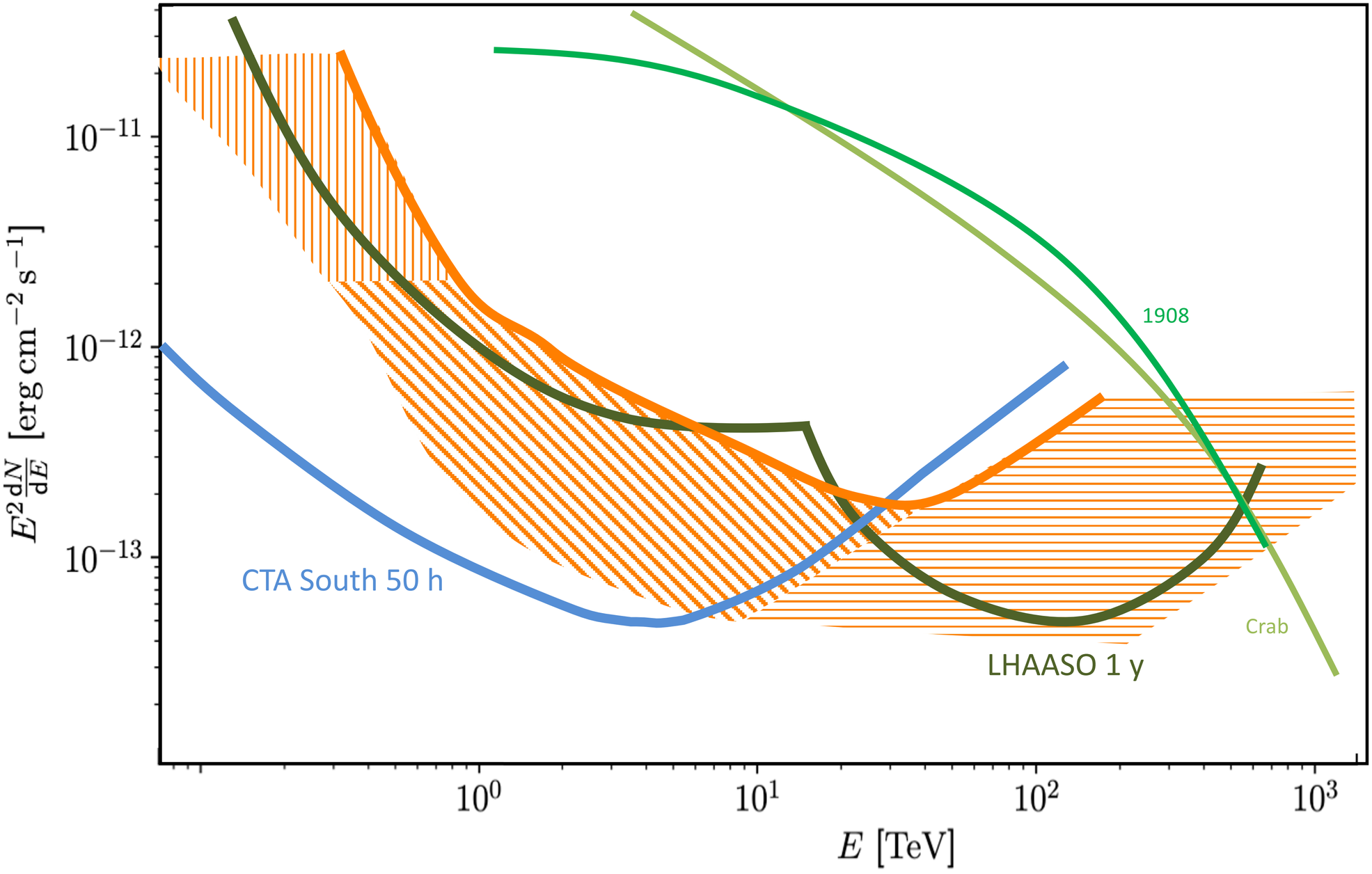
- Larger detector array and increased altitude w.r.t. HAWC
  - → Very precise measurements possible even below 1 TeV

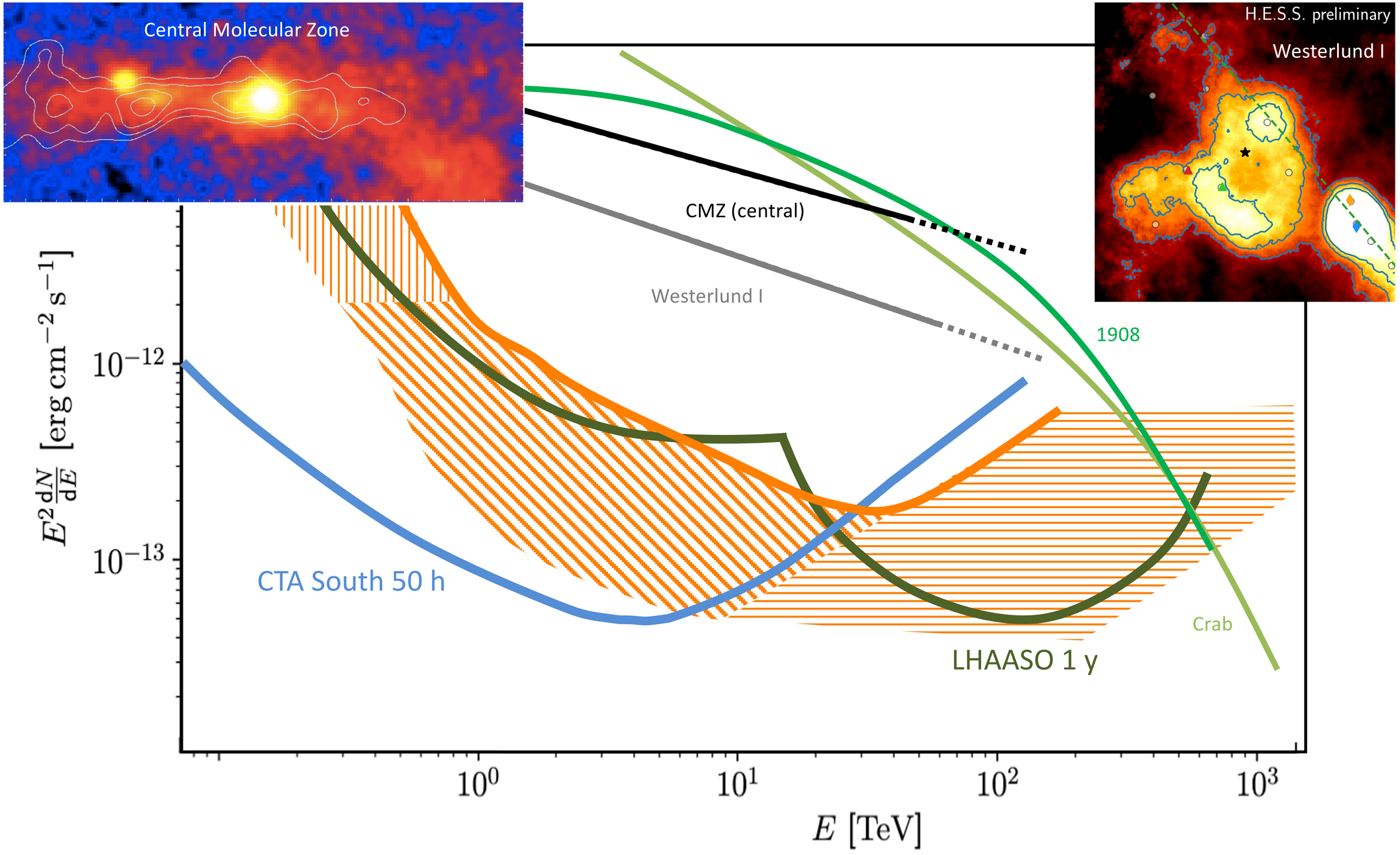

SWGO ‘Strawman’
(scaled HAWC)
1 year
CTA South 50 h
LHAASO 1 y
10^{-11}
10^{-12}
10^{-13}
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
10^0
10^1
10^2
10^3
E [TeV]


SWGO ‘Strawman’
(scaled HAWC)
1 year
Low E enhancement
CTA South 50 h
LHAASO 1 y
10^{-11}
10^{-12}
10^{-13}
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
10^0
10^1
10^2
10^3
E [TeV]

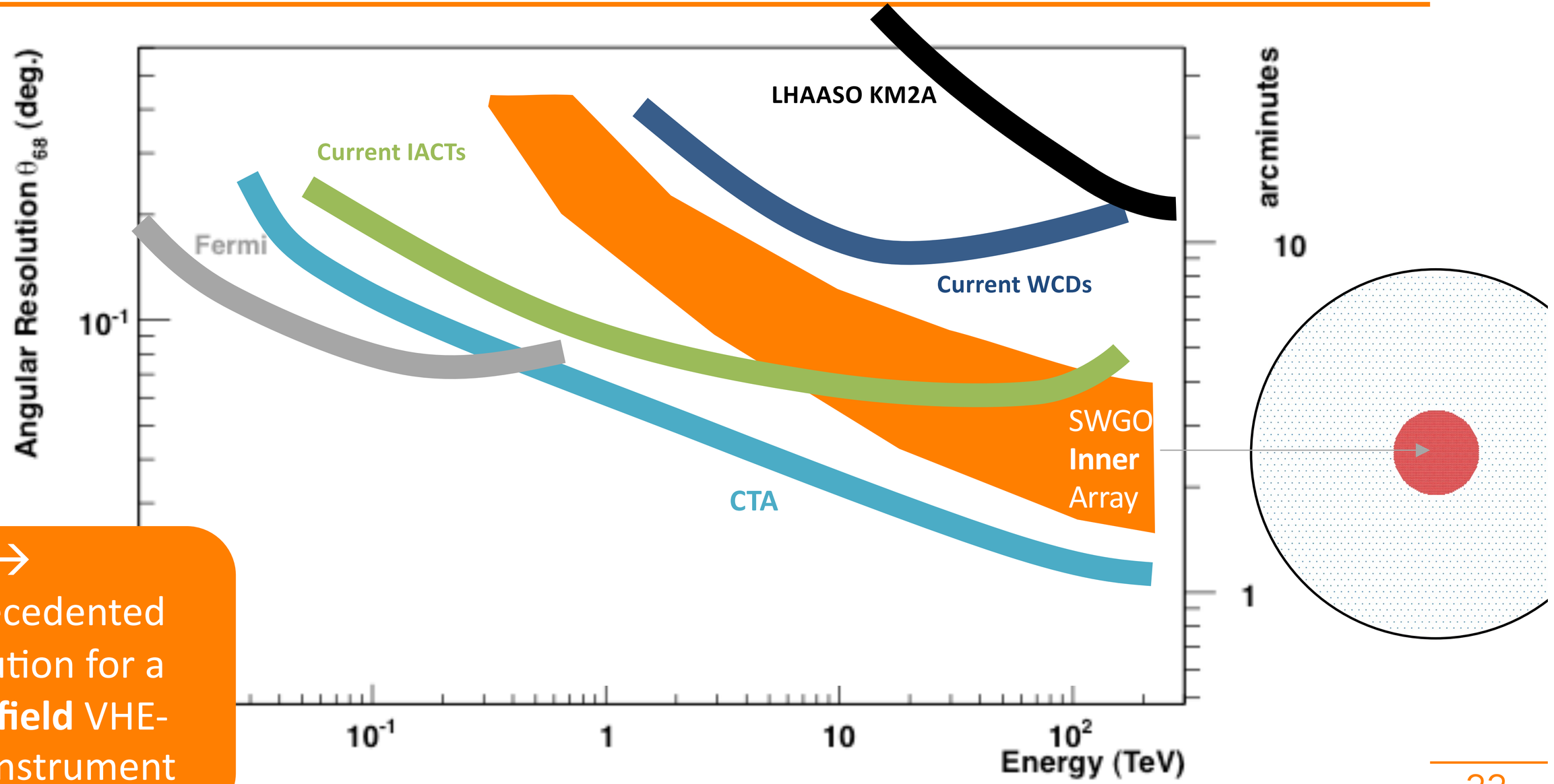

SWGO ‘Strawman’
(scaled HAWC)
1 year
Improved PSF
and BG rejection
CTA South 50 h
LHAASO 1 y
10^{-11}
10^{-12}
10^{-13}
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
10^0
10^1
10^2
10^3
E [TeV]


SWGO Phase Space Exploration
km²+
outer array
CTA South 50 h
LHAASO 1 y
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
E [TeV]
10^{-11}
10^{-12}
10^{-13}
10^0
10^1
10^2
10^3


$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
10^{-11}
10^{-12}
10^{-13}
10^0
10^1
10^2
10^3
E [TeV]
1908
CTA South 50 h
LHAASO 1 y
Crab


Central Molecular Zone
H.E.S.S. preliminary
Westerlund I
CMZ (central)
Westerlund I
1908
CTA South 50 h
LHAASO 1 y
Crab
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
10^{-12}
10^{-13}
10^0
10^1
10^2
10^3
E [TeV]

Resolution?



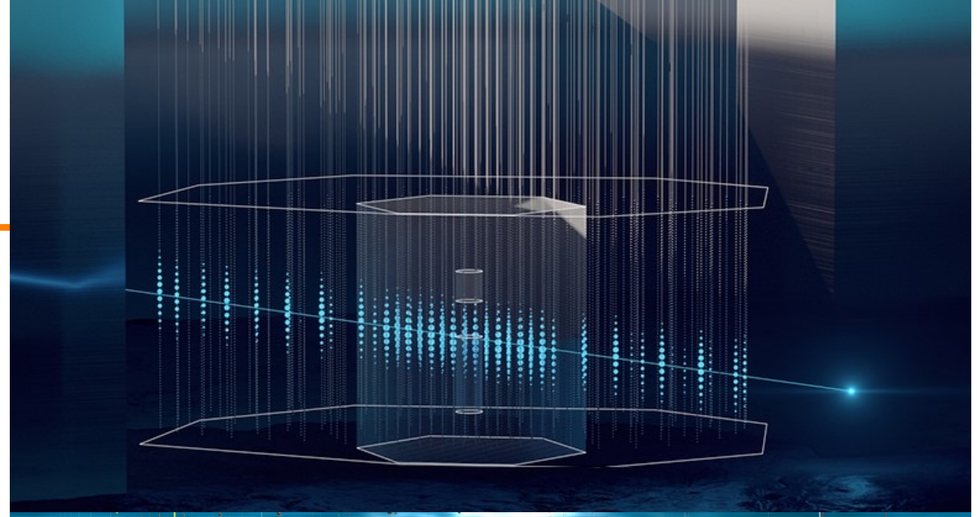
Goal → unprecedented resolution for a **wide field** VHE-UHE instrument

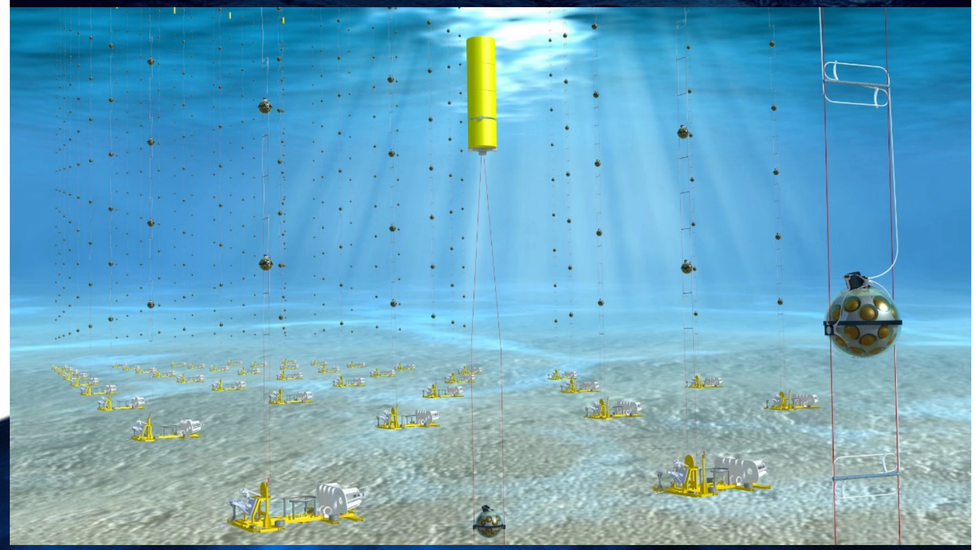
Conclusions

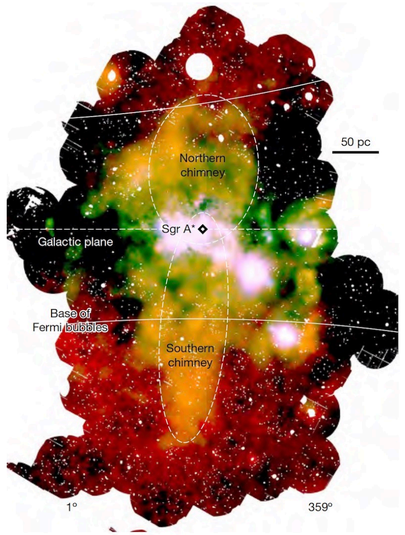
- The Southern Sky needs a wide field VHE-UHE gamma-ray instrument!
  - → Complementing LHAASO – a complete view of the TeV-PeV sky
  - → Strong synergies with CTA and the new generation neutrino telescopes
  - → Transient phenomena, diffuse emission, UHE sources +++
- SWGO advancing towards design and site choices
  - → Despite pandemic!
- Very open for new partners and new ideas
- Looking forward to strong partnerships with LHAASO & CTA

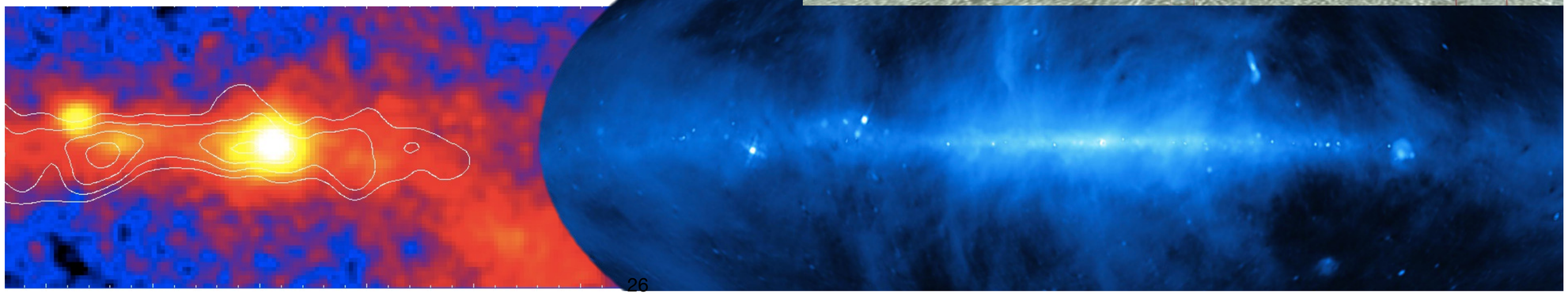
Neutrino Synergies

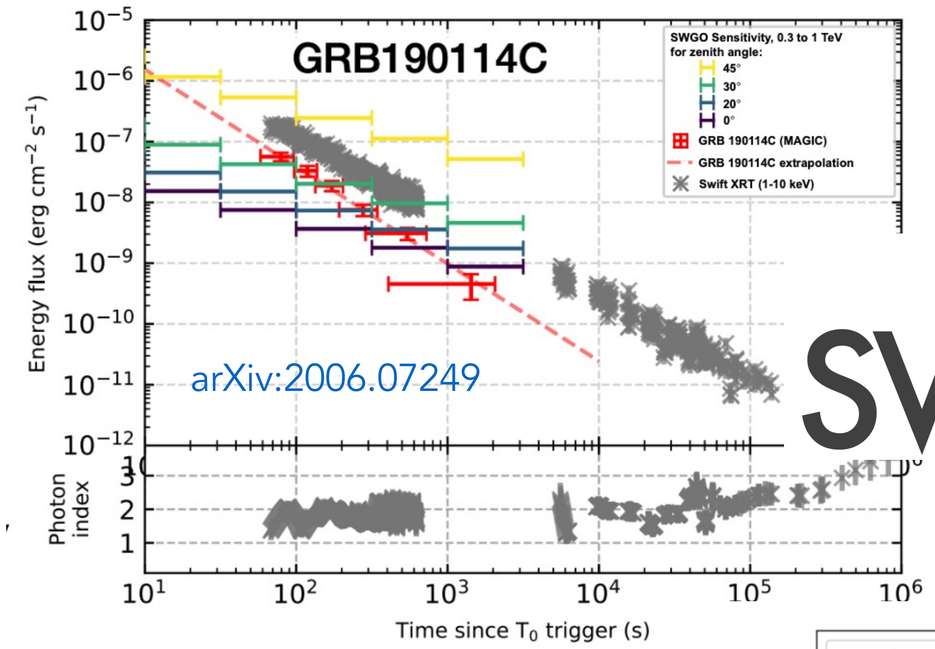
- SWGO+LHAASO
  - → Full sky map of TeV-PeV emission
- Strongly complements new generation of **neutrino instruments**
  - → Mapping out diffuse emission / separating IC + pion decay emission +++



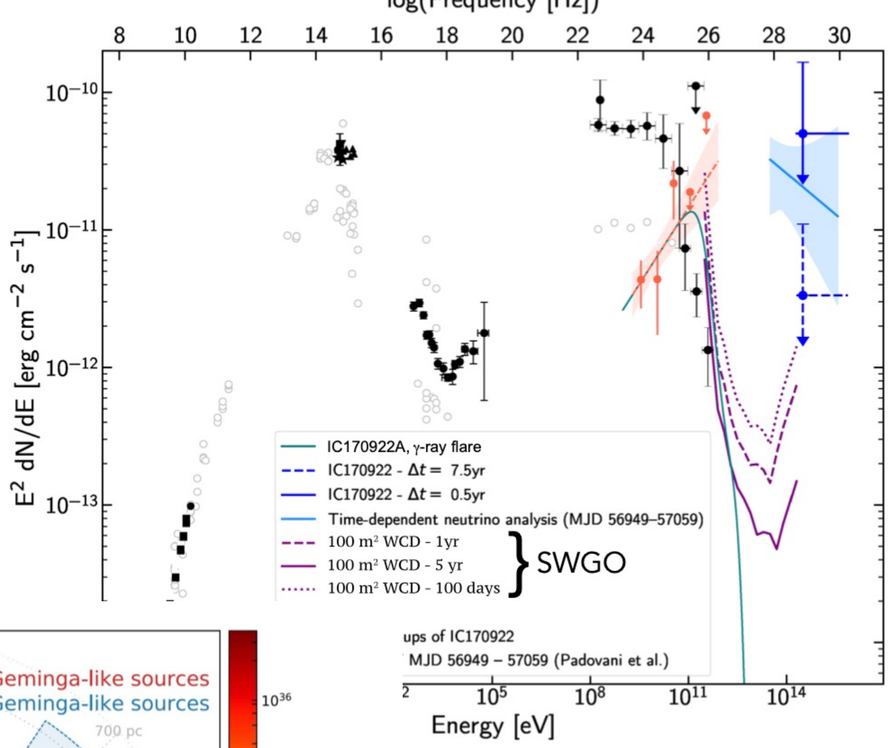






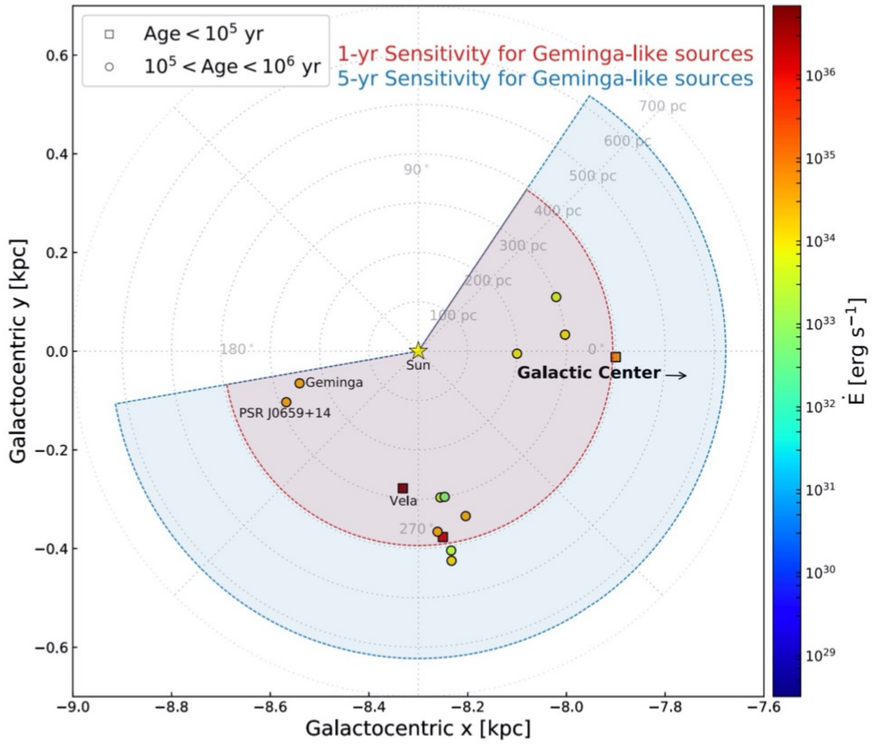


SWGO



Modified from arXiv: 1812.01036

- Early phase **Gamma Ray Bust** sensitivity



- Geminga-like **PWN Halo** Sensitivity

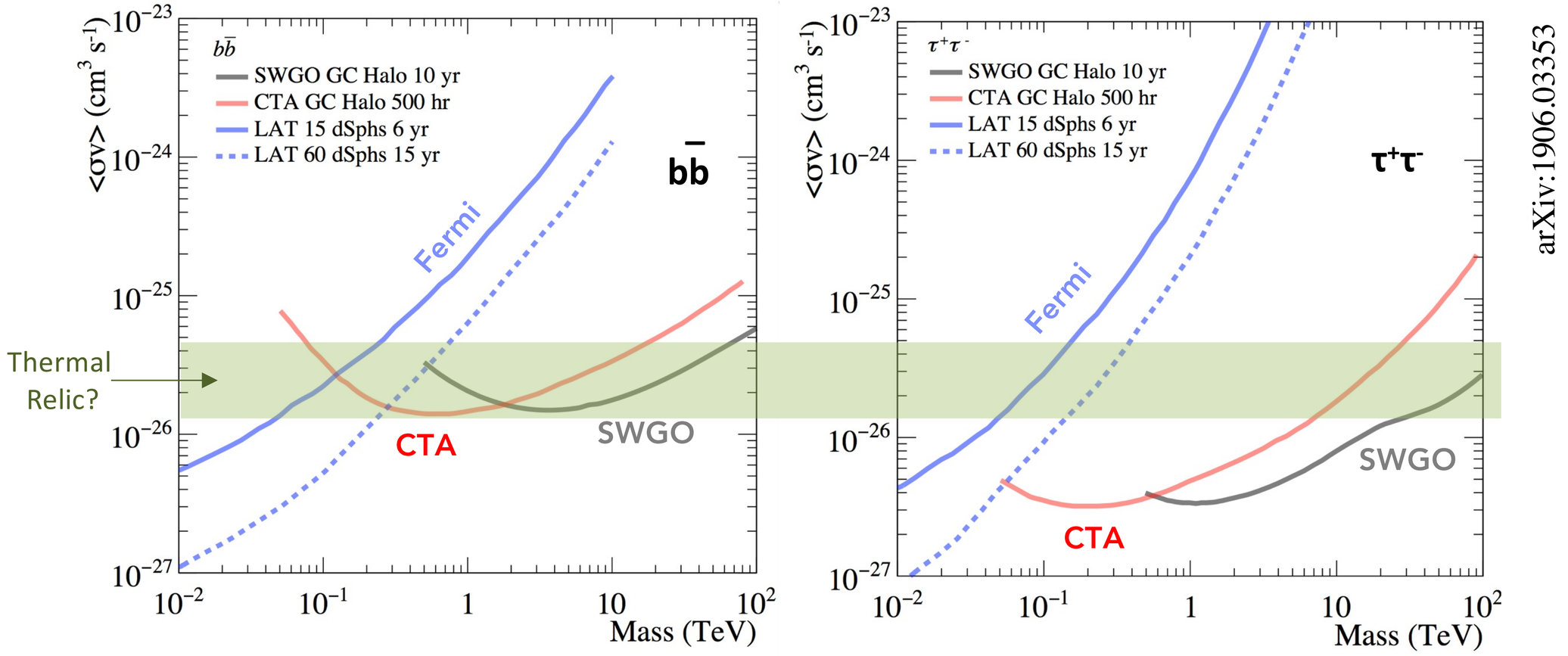
arXiv:1902.08429

- SWGO monitoring CF **TXS 0506+056**

All with pessimistic sensitivity estimates

Dark Matter

- Thermal relic WIMP annihilation signature accessible over a very wide mass range (Galactic Centre/Halo observations @ VHE)



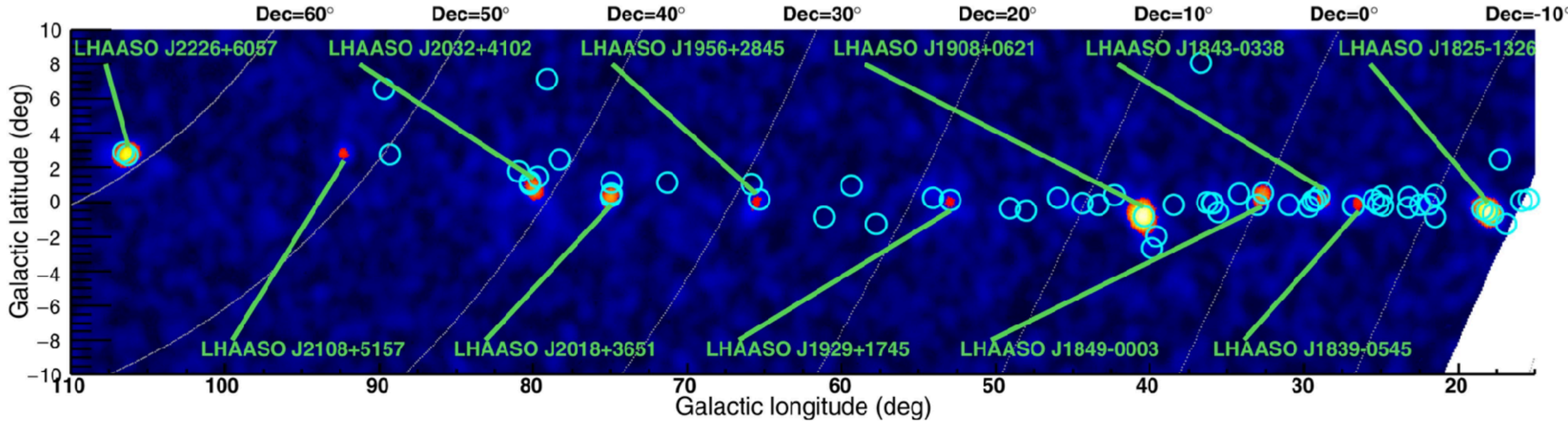
NB Sensitivity improving for both CTA + SWGO – analysis improvements

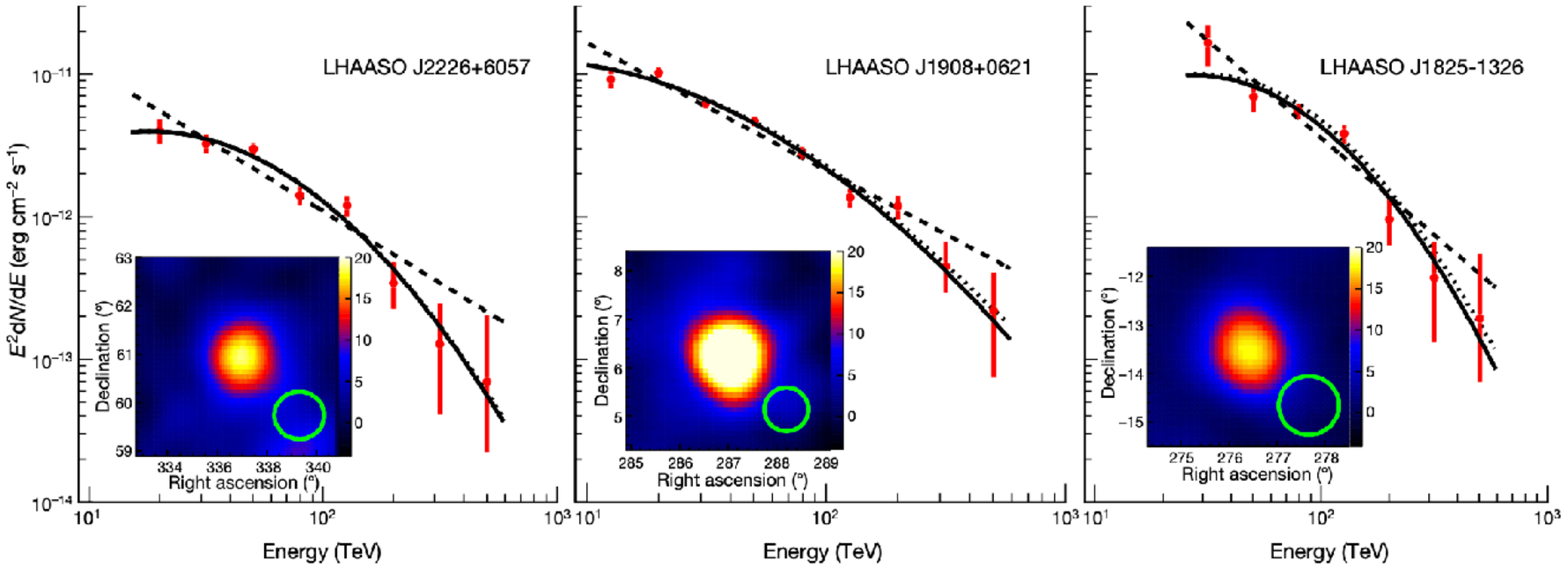
Some highlights: The dawn of ultra-high-energy gamma-ray astronomy

LHAASO

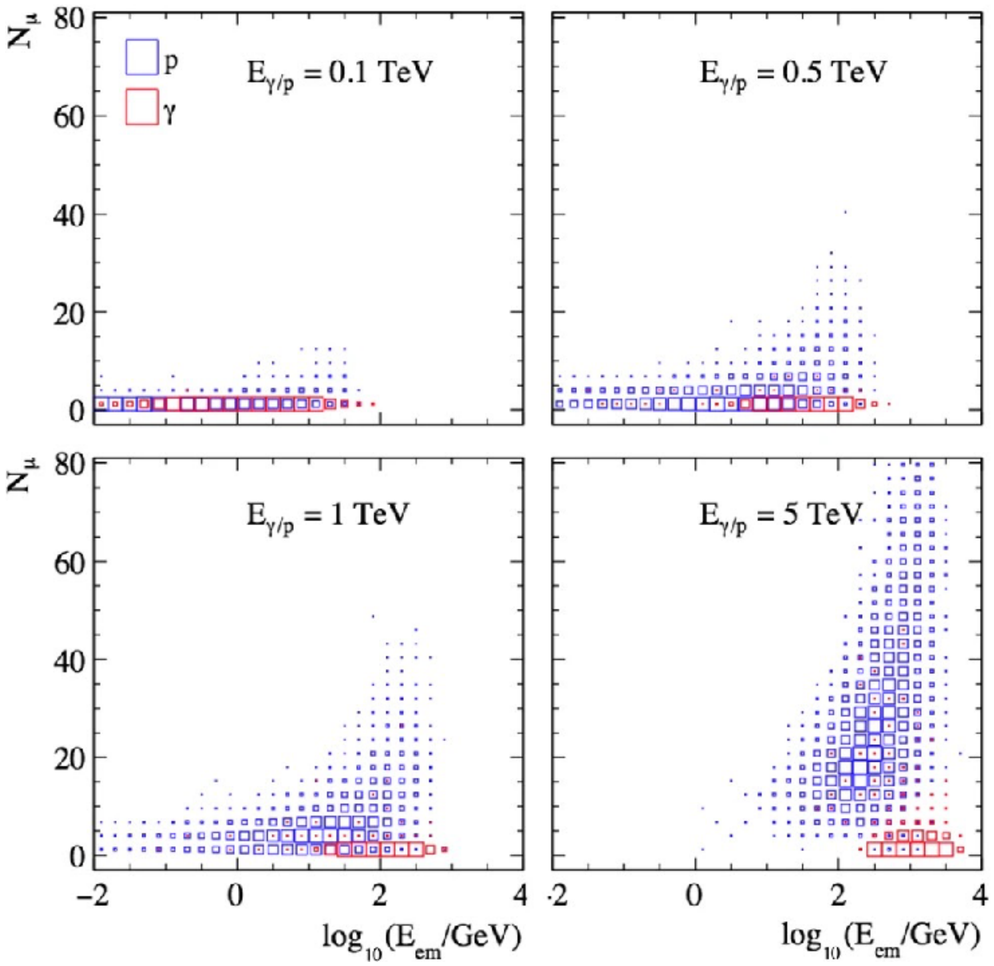
- 12 sources above 100 TeV
- Photons up to PeV energy

Cao, Z., et al,
Nature **594,** 33–36 (2021)

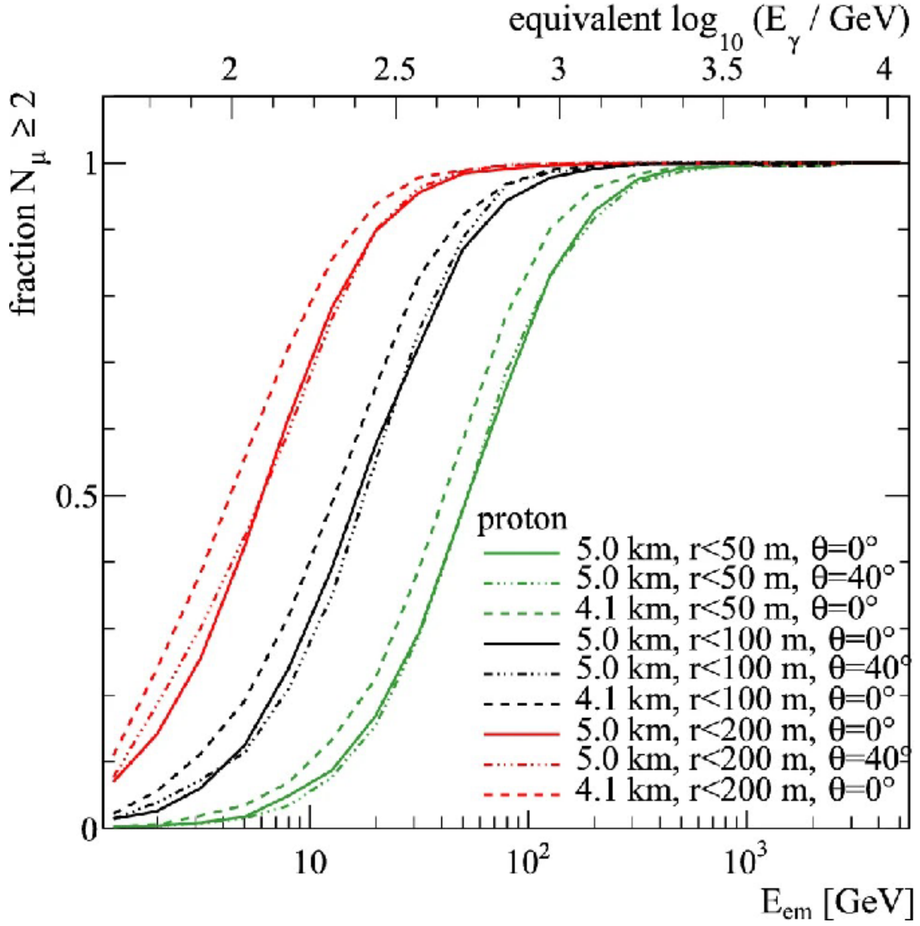




Identifying gamma rays using muons



HS., Hinton, J. & López-Coto, R.
Eur. Phys. J. C 79, 427 (2019).



- Also look to pattern of detector hits!
- How low in energy can we go?


Salta, Argentina
4.8 km above sea level

Reference Configuration

- Establish a plausible, costable and realisable (with existing tech) design to serve as reference to alternative approaches